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INDIAN FOREST UTILIZATION

BY

R. S. TROUP, F.C.H.

Imperial Forest Service, India

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PREFACE.

A SECOND edition of this Manual having become necessary, the opportunity has been taken to revise it and bring it up to date. The Manual is intended primarily as a text-book for use at the Imperial Forest College, Dehra Dun, and as such its scope is limited mainly to the requirements of the College. Some alteration in the general arrangement of the subject matter has been made with a view to increasing its utility for instructional purposes. In this edition the chapter on Transport of Wood has been omitted, since this subject is dealt with in detail under Forest Engineering, and is taught under that branch at the Forest College.

Special acknowledgments are due to Mr. W. Raitt for his kind assistance in dealing with the subject of paper-pulp, to Mr. E. A. Smythies for information on resin-tapping, to Mr. Puran Singh, Forest Chemist, for notes on the distillation of camphor and turpentine and the preparation of tannin extracts, to Mr. Cubitt for assistance in compiling information on baling hay, and to Messrs. Pearson and Irani for notes on hay presses.

DEHRA DUN,
7th March 1912.

PREFACE TO THE FIRST EDITION.

THE present Manual has been written primarily for the use of the students of the Imperial Forest College, Dehra Dun, but if it should prove of some slight use to others the writer will feel more than satisfied.

The only work on Indian Forest Utilization which has hitherto appeared is Fernandez's *Notes on the Utilization of Forests,* published in 1891 : this book has served its purpose well, but with the rapid advance of Forestry in India it has of late years been getting more and more out of date, and the production of an entirely new work on Forest Utilization is now urgently called for. The general arrangement of the present Manual is based more or less on that of Gayer's *Forstbenutzung,* but the details follow as much as possible the practice and experience of Indian Forestry.

The compilation of a Manual of this kind would not have been possible without a large amount of assistance from others, and first and foremost the writer desires to express his deep indebtedness to the Officers of the Indian Forest Department, of all ranks, for the generous assistance which they have rendered in furnishing him with much valuable information.

Among the pricipal works which have been consulted in the preparation of this Manual are Gamble's *Manual of Indian Timbers,* Schlich's *Manual of Forestry, Volume V,* (*Forest Utilization*, by W. R. Fisher), and Watt's *Dictionary of the Economic Products of India*, while much useful information has been obtained from the pages of the *Indian Forester*, and from the various Indian Forest Bulletins and other publications, particularly E. M. Coventry's Bulletin on *Ficus elastica*.

In conclusion the writer wishes to acknowledge the help received from Mr. Moyle, Director of Railway Construction in India, in the form of a most useful note on railway sleepers, and the assistance given by Rai Sahib Upendranath Kanjilal, Instructor at the Imperial Forest College, in conducting much of the correspondence connected with the collection of information for this Manual.

12th April 1907.

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INTRODUCTION.

FOREST UTILIZATION is that branch of Forestry which deals with the most advantageous and suitable methods of collecting, converting, and disposing of forest produce, which can conveniently be divided into two main classes, *Major Forest Produce*, comprising timber and fire-wood, and *Minor Forest Produce*, which includes all other produce of the forest.

The subject matter of this Manual is dealt with under four separate heads :—

I.—*Utilization of Wood or Major Forest Produce.*

II.—*Utilization of Minor Forest Produce.*

III.—*Organization of Labour, and Modes of Sale and Disposal of Wood and other Forest Produce.*

IV.—*Special Forest Industries.*

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PART I.

UTILIZATION OF WOOD.

It is of the utmost advantage to the forester to be able to convert and classify his wood in such a manner that the demands of the market may be satisfied, while at the same time the best value may be obtained for the material disposed of: hence the necessity for an accurate knowledge of the various properties and uses of woods, as well as the best methods of felling trees, converting them into timber and firewood, and bringing the material to the market. These considerations lead to the division of Part I into four chapters:—

I.—*Technical Properties of Wood.*
II.—*Industrial Uses of Wood.*
III.—*Felling and Conversion of Timber.*
IV.—*Wood Depôts.*

The subject of wood transport is one which is fully dealt with under Forest Engineering, and for this reason, although it bears directly on the utilization of forests, it need not concern us here.

CHAPTER I.

Technical Properties of Wood.

There are few materials which vary more in texture, appearance, and utility for various purposes, than wood. Not only do the different species of woods vary greatly, but even woods of the same species grown under different conditions may possess widely diverse characteristics. The differences in the value of woods, and their suitability for various uses, depend on certain technical properties, of which the following are the most important:—

1. Anatomical structure.
2. Shape and size of trees.
3. Specific gravity.
4. Hardness.
5. Flexibility.
6. Elasticity.
7. Fissibility.
8. Strength.
9. Seasoning power, and liability to be affected by moisture.
10. Durability.
11. Combustibility and heating power.
12. Colour, grain, and other properties.
13. Freedom or otherwise from defects or unsoundness.

SECTION I.—ANATOMICAL STRUCTURE OF WOOD.

1. *Dicotyledons and Gymnosperms.*

If the sawn end of a log of timber be examined, it will be seen that the wood is marked with certain definite marks. In the centre will be found a small soft mass of tissue known as the pith, round which are numbers of concentric rings, sometimes called annual rings. These concentric rings, which usually represent the wood produced during one growing season, vary greatly in width, being broad in fast-grown and narrow in slow-grown timber: in many timbers they are not clearly visible. Radiating from the centre outwards are numbers of fine lines, known as *medullary rays,* which vary in distinctness according to the species of timber. Outside the wood is the *cortex* (popularly termed "bark"), while between the wood and the cortex is the *cambium,* a thin layer of soft tissue which, as it grows, produces wood to the inside and cortex to the outside. If the log be split open, it will be found that the concentric rings which have already been seen in cross section are really concentric hollow cylinders of wood laid on one above the other, and which in longitudinal section produce the "grain" of the wood. Further it is seen that the medullary rays are in reality vertical plates running through the concentric layers of wood, and varying in length, depth, and width. These medullary rays produce the shiny appearance known as "silver grain," a quality which renders some woods valuable in the eyes of the cabinet-maker.

The medullary rays differ much in different species. Thus in teak and *sundri* (*Heritiera minor*) they are moderately broad and uniform; in the oaks, *Rhododendron arboreum,* and *Dillenia indica* they are of two kinds, a few broad and at irregular intervals, separated by numerous fine ones; in *Dalbergia Sissoo, Buxus sempervirens,* and conifers they are fine to very fine and usually numerous.

In most species the wood in the inside is darker, harder, and somewhat drier than that of the outer layers; this dark inner wood is called *heartwood,* and the lighter-coloured outer wood is called *sapwood.*

Heartwood is formed by the deposition of colouring matters and other substances in the cells or on the walls of the cells and other tissues of the wood, whereby the walls get thicker and lignified, and the wood thus becomes denser and heavier. Some trees have no distinct heartwood, for instance *Mangifera indica, Adina cordifolia, Bombax malabaricum, Ficus bengalensis, Terminalia belerica, Cochlospermum Gossypium, Ægle Marmelos, Zizyphus Jujuba, Butea frondosa, Erythrina* spp., *Pongamia* spp., *Gardenia* spp., etc.

Wood is made up of three chief kinds of component elements, *wood-vessels, wood-fibres,* and *wood-cells.* These, however, do not all occur in every kind of wood.

Wood-vessels.—If the transverse section of a piece of teak-wood be examined, it will be found that the annual rings are sharply defined by one or more lines of pores, which can be distinctly seen with the naked eye. These pores, which are known as *vessels*, are seen on a longitudinal section to be tubes running longitudinally through the wood. Between the rings of pores will be found a quantity of denser wood which may contain scattered pores. That part of the annual ring which contains these pores in large numbers is known as *spring-wood*, having been formed at the beginning of the growing season, whereas the denser tissue filling up the remainder of the annual ring is called *summer-wood* or *autumn-wood.*

Although these vessels are fairly large and evenly distributed in teak-wood it does not follow that they can be so easily seen in all woods. The arrangement and size of the vessels in fact vary so much in different species, that woods can, to a certain extent, be classified according to the arrangement of their vessels. Thus the vessels are large and fairly evenly distributed in *Bombax malabaricum*, *Xylia dolabriformis*, and *Ficus bengalensis;* large, numerous, and unequally distributed in *Terminalia tomentosa*, *Cedrela Toona*, and *Acacia arabica ;* small and evenly distributed in the maples, the willows, *Ægle Marmelos*, *Chloroxylon Swietenia*, *Adina cordifolia*, and *Holarrhena antidysenterica ;* and extremely small and evenly distributed in boxwood. In some woods the pores occur in groups or in chains, for instance in *Mesua ferrea*, *Melia indica*, *Anogeissus latifolia*, *Lagerstrœmia parviflora*, *Bassia latifolia*, and the oaks. The arrangement of the vessels often determines the distinctness or otherwise of the concentric rings in timber. Apart from the fact that each concentric ring in some species does not represent exactly one year's growth, the even distribution of the vessels through spring-wood and autumn-wood alike frequently makes the accurate counting of annual rings an impossibility, even if the vessels themselves are large enough to be visible without difficulty. In coniferous timber vessels are, except immediately round the pith, entirely absent, but the concentric rings, which are normally always annual, are distinct, owing to the dense structure of the autumn-wood as compared with the spring-wood.

Wood-fibres are the principal elements of wood. They are elongated structures with closed pointed ends, and with their walls more or less thickened, sometimes to such an extent that their *lumina*, or internal spaces, are much contracted. Fibres vary in form, some kinds containing protoplasm and starch, and others containing none of these substances.

Coniferous wood is almost entirely composed of elements resembling fibres, and known as *tracheids*. These are characterized by the presence of large bordered pits on their walls. In the spring-wood the tracheids have thin walls and large lumina, whereas in the autumn-wood they are much compressed, having thick walls and smaller lumina. This compression of the tracheids in the autumn-wood results in that wood being much harder, and usually darker in colour, than the spring-wood, rendering the annual rings distinct, although the structure of coniferous wood is more regular than that of broad-leaved species.

Wood-cells form the rather thin-walled soft tissue known as *parenchyma*. These cells are not so conspicuously elongated as vessels and fibres, and they frequently contain starch, being the storehouses of reserve material. Wood-cells are usually absent in coniferous wood, except in medullary rays and round *resin-ducts*. These resin-ducts are spaces surrounded by resin-forming cells ; they run both longitudinally up the tree and radially along the medullary rays.

2. *Monocotyledons*.

The structure of monocotyledonous wood is totally different from that of dicotyledons or gymnosperms. One great difference is the absence of medullary rays. The stems are generally full of parenchymatous tissue of a more or less loose texture. This tissue is traversed by what are known as *fibro-vascular bundles*, that is, rather thick strands of harder tissue consisting of vessels and fibres connected together into bundles. In the palms these bundles follow a wavy course up the stem, while in the bamboos and canes they run parallel to each other up the internodes.

Another peculiarity of monocotyledons is that there is no heartwood. The centre of the stem is either hollow as in most bamboos, or full of soft parenchymatous tissue, which is often very rich in starch, and is the least lignified part of the stem, whereas the outermost wood is the most compact and the hardest ; this structure is typically seen in palms.

The growth in thickness of monocotyledons differs from that of dicotyledons. We have seen that dicotyledons increase in thickness by laying on concentric rings of wood from the layer of growing cells known as the cambium, which is situated between the wood and the cortex. In monocotyledons, however, the growth in thickness takes place at certain points within the stem, and we thus find no annual rings. In monocotyledonous trees, such as palms and bamboos, the stems reach their maximum thickness at an early stage in their height growth, and do not continue growing in thickness throughout their life as do the stems of dicotyledons.

SECTION II.—SHAPE AND SIZE OF TREES.

The three main parts of a tree from which wood is obtained are the *stem*, the *branches*, and the *roots*. Of these the wood of the stem is the most important, as it is from the stem that wood fit for timber is almost invariably obtained. It is therefore the aim of the forester in most cases to produce trees having the maximum proportion of stem-wood. The chief factors which influence the shape and dimensions of trees, as well as the proportion of stem-wood, branch-wood, and root-wood, are (1) *the species*, (2) *the density of the crop*, (3) *the age of the tree*, (4) *the soil and locality*, (5) *the sylvicultural system adopted*. These will be dealt with in turn.

(1) SPECIES.

When grown in isolated positions different species of trees differ greatly in their mode of growth, particularly as regards the relative size of bole and branches.

Certain trees, of which the firs and some other conifers are the best examples, produce tall straight stems with definite leaders and numerous but relatively small side branches. Among broad-leaved species *Sterculia alata* and *Saccopetalum tomentosum* are somewhat similar in type. *Bombax malabaricum* is also of this type, but its whorled branches are usually massive. Comparatively long clean boles are frequently produced in the open by pines, many palms, *Casuarina*, and certain species of *Dipterocarpus*, *Eucalyptus*, etc. On the other hand there are many species which usually produce short boles and large low crowns when grown in the open; of these the mango, the oaks, *Cedrela Toona*, *Mesua ferrea*, *Schleichera trijuga*, *Eugenia Jambol-*

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dna, *Cassia Fistula*, *Lagerstrœmia Flos-Reginœ*, and *Albizzia Lebbek*, are examples.

Certain trees tend to branch low down even when grown in moderately dense forest, for example *Taxus baccata*, *Bassia latifolia*, *Ficus glomerata*, *Rhododendron arboreum*, *Careya arborea* and *Schleichera trijuga*.

(2) DENSITY OF THE CROP.

It is a well-known fact that trees grown in a dense crop produce long clean boles and small crowns. Thus the proportion of stem-wood in such trees is much greater than that of similar trees grown in the open. This applies especially to those trees which have a natural tendency to branch low down when grown in the open.

(3) AGE OF THE TREES.

Actual measurements in Europe show that in trees grown in canopied forest the amount of branch-wood in early youth exceeds that of stem-wood fit for use. As the tree reaches middle age the proportion of stem-wood predominates, and increases as the tree grows older, when the proportion of branch-wood may eventually fall to as little as 10 per cent. Although similar accurate measurements are not yet available in India, general observations lead to the same conclusions, although the actual proportion of wood from the several parts of the tree will no doubt vary under different conditions. The actual quantity of wood in the roots as a rule increases as a tree grows up towards maturity, but the proportion of root-wood to stem-wood probably varies according to the proportion of branch-wood to stem-wood.

(4) SOIL AND LOCALITY.

As a general rule the more favourable the locality the greater the proportion of stem-wood in a tree and the larger the quantity produced. The extent of root development, however, is, as a rule, the converse of this, particularly in localities which are unfavourable owing to lack of moisture in the soil, in which case the roots spread far and wide in search of water. The abnormal development of the root system of trees as an adaptation to peculiar conditions of soil and locality is strikingly exemplified in *Prosopis spicigera* and *Heritiera minor*. The former tree, which grows in the

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arid regions of the Punjab, Sind, Rajputana, and elsewhere, in its search for moisture in the subsoil produces an abnormally long tap-root, one specimen of which has been measured to be 86 feet in length. *Heritiera minor*, the *Sundri* of the Sunderbans, grows in tidal regions occasionally inundated by salt water. It adapts itself to the peculiar circumstances of the locality by producing roots which spread laterally near the surface of the ground, sending up perpendicular blind shoots a foot or more in height above the ground; these shoots, which resemble inverted tent-pegs, possibly act as breathing organs when the ground is flooded. The Mangroves, also, which grow in muddy tidal forests, have a largely developed root system, the stems being supported by buttressed roots standing out of the mud.

(5) SYLVICULTURAL SYSTEM.

The various sylvicultural systems known to European Forestry have not yet been practised in India to such an extent as to enable us to judge accurately of the merits of each for the production of large-sized and well-shaped timber. Briefly stated, the following may be said to be the conclusions arrived at on a comparison of the chief sylvicultural systems, based to a considerable extent on European experience and statistics:—

A.—High Forest.

(*a*) *The clear cutting system.*—The quality of the timber produced, as far as shape, length, and cleanness of bole are concerned, is equal to or better than that of any other high forest system, especially if the crop has been created by planting. The quantity of timber produced per acre compares favourably with the quantity produced under other systems. In India doubts are frequently expressed, particularly with regard to teak, as to whether plantation grown timber will be equal in technical properties to natural timber. Exhaustive tests of plantation timber grown under different conditions will be necessary when our plantations approach maturity: in the meantime such tests as have hitherto been carried out tend to show that in most cases teak grown in plantations is in no way inferior to naturally grown timber, so far as strength is concerned.

(*b*) *The uniform method* (*system of successive fellings*).—The quantity of timber produced is probably equal to that produced under the clear-cutting system, while in cleanness and straightness the high quality of the timber produced is, like that of the clear-cutting system, characteristic of even-aged woods, and superior to that produced in uneven-aged woods. Under the uniform method those trees left for the final felling have a chance of attaining a large diameter owing to their open position during the later portion of their life.

(*c*) *The group system.*—The timber produced under this system probably approaches but hardly equals that produced under the last system. Statistics, however, are wanting.

(*d*) *The selection system.*—Accurate comparative figures as to volume are not available. Under this system less clean, shorter, and more tapering boles are produced than under the system of successive fellings.

(*e*) *Two-storied high forest.*—This system is well suited for the production of large-sized as well as straight clean timber, the trees in each storey being even-aged.

B.—Coppice Systems.

(*a*) *Coppice.*—This system is suitable for the production of fuel and small sized timber, but not for large timber.

(*b*) *Coppice with standards.*—The trees produced in the overwood compare unfavourably with those produced under the high forest systems, as the boles are shorter and less clean.

The sylvicultural systems have here been dealt with entirely from the point of view of the quantity and quality of the timber produced, irrespective of other considerations.

Before leaving the subject of the shape and size of the trees we may define what is meant by the ideal timber tree from an economic point of view. The bole of such a tree should have four chief qualities—cleanness, straightness, cylindrical shape, and suitable dimensions. Sylviculture teaches us how trees possessing these qualities are produced. Stated briefly, the first three are obtained by growing the young crops in a crowded state, and afterwards judiciously thinning the woods so that the stems may increase in girth to the desired size. The time when the woods should be opened out depends largely on the species and the local conditions, but for the production of long clean boles no severe interruption of the leaf canopy should take place until the trees have approached their full height growth. The dimensions to be attained will depend on the purpose for which the wood is required and on the demands of the market.

SECTION III.—SPECIFIC GRAVITY.

1. *General.*

By the *specific gravity* of a wood we mean the ratio which the weight of a certain volume of the wood bears to the weight of an equal volume of cold water. As one cubic foot of cold water weighs 1,000 ounces or 62½ lbs., the actual weight of a cubic foot of any wood is obtained by multiplying 62½ lbs. by the specific gravity of the wood; and conversely the specific gravity of any wood may be found by dividing the weight of a cubic foot by 62½ lbs. The determination of the specific gravity of wood is explained in the *Manual of Forest Mensuration.*

The weights of various woods are frequently expressed in pounds per cubic foot, those which float on water weighing less, and those which sink weighing more than 62½ lbs. per cubic foot.

Specific gravity as a property of wood is only of secondary importance when compared with certain other properties such as strength, durability, and soundness, but at the same time it deserves careful consideration owing to its close connection with other properties such as hardness, combustibility and heating power, seasoning power, and durability. Specific gravity also comes into consideration where great weight is a disadvantage, for example in timber for roofing, frames of carriages, masts and spars of ships, light packing-cases, etc. Again in the case of heavy woods the cost of transport may be considerably higher than for light woods, while extraction may be rendered quite impossible where the only export routes are small floating streams where there is no room to buoy up heavy timber by attaching it to boats or to lighter logs. It should be noted, in this connection, that the capacity of a wood for being transported in floating streams does not necessarily depend on its specific gravity, since some woods absorb more water than others during floating; certain woods, therefore, whose specific gravities are less than unity, cannot be floated unaided for long distances owing to their tendency to become water-logged.

2. *Factors causing Differences in the Specific Gravity of Woods.*

The researches of Sachs and R. Hartig have shown that the actual substance of wood, that is, the cellulose of the cell-wall, differs little in specific gravity for different species of woods, being about half as heavy again as water. It is evident, therefore, that there must be certain factors which account for the great differences in the specific gravity of different woods. The chief factors are (1) anatomical structure of the wood, (2) soil and locality, (3) age of the tree, (4) amount of moisture in the wood, (5) amount of resin and other substances, (6) part of the tree from which the wood is taken.

(1) ANATOMICAL STRUCTURE.

The specific gravity of a wood depends mainly on the quantity of woody substance in its tissues, that is, the thicker the cell-walls and the smaller the lumina, the higher the specific gravity of the wood. According to Hartig, the broad-leaved species of Europe have from 25 to 30 per cent. more woody substance in their tissues than conifers, and in India it would be reasonable to suppose that the difference between some of the heaviest and some of the lightest woods in this respect is even greater. In many species the tissues of the autumn-wood are denser and therefore heavier than those of the spring-wood, which are porous. This is exemplified particularly in conifers. If we examine a piece of slow-grown coniferous wood we find that the rings of dense dark-coloured autumn-wood are separated by narrow zones of porous spring-wood: if the wood be fast-grown these zones of denser autumn-wood, which remain fairly constant in width, are widely separated by broad zones of porous spring wood. Thus in conifers as a general rule slow-grown wood is heavier than fast-grown wood. In broad-leaved species containing large pores in the spring-wood and denser tissues in the autumn-wood the opposite is usually the case, the fast-grown wood, in which the porous zones of spring-wood are widely separated by denser autumn-wood, being heavier than slow-grown wood where the porous zones are close together. This is true, however, only within certain limits, and provided the growth is not too fast; the rule also admits of exceptions. In the case of broad-leaved species having the pores more or less evenly distributed through the spring and autumn-wood no definite rule can be laid down.

(2) SOIL AND LOCALITY.

The main conditions which tend to increase the weight of wood are sufficient nourishment and moisture in the soil and the necessary amount of warmth and sunlight. Excess of moisture in the soil often renders wood soft and spongy, decreasing its specific gravity, while the same condition may be brought about by insufficient sunlight. Experiments sometimes show that woods from certain localities are heavier than woods of the same species from other localities. Thus *Chir* (*Pinus longifolia*) wood from Sikkim is somewhat heavier, harder, and stronger than that of the North-West Himalayas : *Bombax malabaricum* is lighter in Bengal and Assam than in the Central Provinces. The factors which cause these differences may not, however, be the same in either case.

(3) Age of the Tree.

The actual woody substance formed by young trees is usually heavier than that formed by old trees. On the other hand the formation of heavy heartwood during middle age may render the average specific gravity of the wood of old trees considerably higher than that of young trees : hence no definite rule can be laid down as to the effect of the age of a tree on the specific gravity of the wood, particularly in the case of trees which form a distinct heartwood.

(4) Amount of Moisture in the Wood.

Hitherto the amount of water in the wood has not been considered ; it exercises, however, a great influence in increasing the specific gravity of woods of one and the same species. In practice we distinguish between (*i*) *Green* or freshly felled wood, which contains on an average 45 per cent. of water, (*ii*) *Forest-seasoned* wood, that is, wood which has become partly seasoned by lying in the forest for some time, and (*iii*) *Completely seasoned* wood, which has lain in an airy shed until it has lost all the moisture which it can part with under ordinary atmospheric conditions ; in this case the amount of water in the wood may be under 10 per cent. Where the term "air-dried" is used below it is intended to refer to completely seasoned wood. The difference in specific gravity between green and dry timber may become a matter of great importance where capacity for floating is concerned. Thus in Burma, where the extraction of teak is almost entirely carried out by floating, it is necessary to kill the teak trees by girdling and allow them to dry for three years before felling, so that they may become light enough to float easily.

The following figures, compiled from the results of tests carried out by the writer, will serve to illustrate the difference between the respective weights (in pounds per cubic foot) of specimens cut from freshly-felled trees and the same specimens after being kept till thoroughly air-dry :—

Species.	WEIGHT IN LBS. PER CUBIC FEET.		Loss of weight per cent. in drying.
	Green.	Air-dry.	
Abies Pindrow (average of 2 specimens)	51·9	30·7	41
Acacia Catechu	79·9	59·9	25
Albizzia procera	67·4	43·4	36
Bombax malabaricum	56·4	25·1	55
Boswellia serrata	66·1	36·1	45
Buchanania latifolia	54·6	32·7	40
Cedrus Deodara (average of 3 specimens)	56·0	35·0	37
Chloroxylon Swietenia (average of 2 specimens)	69·0	53·5	23
Dalbergia Sissoo	70·2	60·5	14
Gardenia latifolia	65·6	49·8	24
Garuga pinnata	65·6	35·7	45
Kydia calycina	50·7	36·7	27
Lagerstrœmia parviflora	68·7	43·3	37
Odina Wodier	66·0	37·1	44
Ougeinia dalbergioides	75·7	54·7	28
Picea Morinda	55·6	28·6	48
Pinus excelsa (average of 3 specimens)	52·5	25·3	52
Pinus longifolia	56·5	30·1	47
Populus ciliata	42·2	28·2	33
Quercus dilatata (average of 2 specimens)	69·6	56·6	19
Quercus incana	70·7	54·1	23
Quercus semecarpifolia (average of 2 specimens)	68·5	55·5	19
Shorea robusta	70·1	45·4	35
Spondias mangifera	45·1	23·9	47
Terminalia tomentosa (average of 2 specimens)	69·6	47·1	32

These figures indicate that as a general rule soft woods lose relatively more weight in drying than hard woods. In the above statement all the woods which lose 40 per cent. of their weight or more are soft woods, while all those which lose less than 25 per cent. are hard woods.

(5) AMOUNT OF RESIN AND OTHER SUBSTANCES.

The dry weight of wood is increased by the amount of resin or oil contained in it. Thus in conifers the narrow ringed resinous wood of the branches is heavier and harder than the wood of the stem, while the wood at the base of the tree and in the larger roots, being highly impregnated with resin, is considerably heavier than the stem-wood. Among other substances which tend to increase the specific gravity of wood may be mentioned the colouring matter deposited in the tissues of the heartwood of many species, for example in ebony, where the black colour is due to deposits of black colouring matter within the cells, and not to any change in the cell-walls. The influence of reserve nutrient material (proteids, starch, etc.), on the specific gravity of wood is, according to Th. Hartig, considerable, but the researches of R. Hartig have thrown serious doubt on this opinion. Wood injected with creosote or metallic salts increases in specific gravity.

(6) Part of the Tree from which the Wood is taken.

In the case of air-dried wood the following general rules hold good in the majority of cases :—

(*a*) According to European experience branch-wood is usually heavier and root-wood lighter than stem-wood. Exceptions to this rule occur in the case of (*i*) slow-grown branches of trees which have large pores in the spring-wood, (*ii*) the thick ends of the roots where they join the stem ; these are sometimes heavier than the stem-wood, (*iii*) roots of conifers which are rich in resin, and whose specific gravity is sometimes greater than that of water. According to Nördlinger the specific gravity of the smaller roots of a tree is less than that of the larger roots.

As far as Indian woods are concerned further trials will be necessary before coming to any definite conclusion regarding the relative specific gravities of stem-wood, branch-wood and root-wood, both in the green and in the air-dry state. In the following statement, showing the results of a few tests made by the writer with green wood, the number of cases in which stem-wood is heavier than branch-wood is more or less the same as the number of cases in which the converse is the case.

Statement showing weight in pounds per cubic foot of green stem-wood and branch-wood from the same tree.

Species.	Weight in pounds per cubic foot.		
	Stem-wood.	Larger branch-wood.	Smaller branch-wood.
Adina cordifolia	63·3	59·0	59·8
Anogeissus latifolia	66·4	62·5	61·1
Carallia integerrima	69·2	68·2	73·5
Erythrina suberosa	62·6	67·1	71·8
Garuga pinnata	61·8	58·9	54·1
Hymenodictyon excelsum	56·0	54·7	58·1
Limonia acidissima	67·4	63·2	58·8
Odina Wodier	59·0	56·9	50·6
Sterculia villosa	49·0	55·8	62·5
Wrightia tomentosa	52·6	48·8	47·6
Zizyphus Jujuba	61·6	61·9	61·7

(*b*) Heartwood is usually heavier than sapwood where a distinct heartwood exists. Where there is no distinct heartwood the inner zones of wood often have the same specific gravity as the outer zones, and may even be lighter. In the case of palms the outer part of the stem is heavier than the inside.

(*c*) Burrs, knots, wavy wood, and sound wood growing over wounds, are usually heavier than ordinary wood; decayed wood, on the other hand, is lighter.

3. *Classification of Woods according to their Weight in Pounds per Cubic Foot.*

The following is a list of some of the principal Indian woods, arranged in classes according to their average air-dry weight in pounds per cubic foot (heartwood being under-

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stood in the case of trees which produce a distinct heartwood):—

(i) *Extremely heavy. 70 lbs. and over.*

1. *Hardwickia binata.*
2. *Tamarindus indica.*
3. *Pterocarpus santalinus.*
4. *Soymida febrifuga.*
5. *Diospyros Ebenum.*
6. *Mesua ferrea.*

(ii) *Very heavy. 60 lbs. and over, and under 70 lbs.*

1. *Pterocarpus indicus.*
2. *Schleichera trijuga.*
3. *Heritiera minor.*
4. *Dalbergia Oliveri.*
5. *Acacia Catechu.**
6. *Xylia dolabriformis.*
7. *Quercus dilatata.*
8. *Q. incana.*
9. *Anogeissus latifolia.*
10. *Bassia latifolia.*
11. *Santalum album.*
12. *Terminalia tomentosa.*
13. *Shorea obtusa.*

(iii) *Heavy. 50 lbs. and over, and under 60 lbs.*

1. *Pterocarpus macrocarpus.*
2. *Cassia Fistula.*
3. *Prosopis spicigera.*
4. *Chloroxylon Swietenia.*
5. *Dalbergia latifolia.*
6. *Melanorrhœa usitata.*
7. *Buxus sempervirens.*
8. *Dipterocarpus tuberculatus.*
9. *Pterocarpus Marsupium.*
10. *Shorea robusta.*
11. *Acacia leucophlœa.*
12. *Ougeinia dalbergioides.*
13. *Acacia arabica.*
14. *Pentacme suavis.*
15. *Terminalia Chebula.*
16. *Quercus semecarpifolia.*
17. *Lagerstrœmia parviflora.*
18. *Melia indica.*
19. *Albizzia Lebbek.*
20. *Dalbergia Sissoo.*
21. *Odina Wodier.*
22. *Careya arborea.*
23. *Chickrassia tabularis.*
24. *Grewia tiliæfolia.*

(iv) *Moderately heavy. 40 lbs. and over, and under 50 lbs.*

1. *Hopea odorata*
2. *Dipterocarpus turbinatus.*
3. *Zizyphus Jujuba.*
4. *Pterocarpus dalbergioides* (Andamans *Padauk*).
5. *Terminalia belerica.*
6. *Eugenia Jambolana.*
7. *Dipterocarpus alatus.*
8. *Lagerstrœmia Flos-Reginæ.*
9. *Tectona grandis.*
10. *Adina cordifolia.*
11. *Dillenia indica.*
12. *Ægle Marmelos.*
13. *Pinus longifolia.*
14. *Taxus baccata.*
15. *Schima Wallichi.*
16. *Juglans regia.*
17. *Sterculia urens.*
18. *Mangifera indica.*
19. *Anthocephalus Cadamba.*
20. *Artocarpus integrifolia.*
21. *A. Lakoocha.*

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* *Acacia Catechu* var. *Sundra* is considerably heavier than the ordinary variety.

(v) *Light.* *30 lbs. and over, and under 40 lbs.*

1. *Butea frondosa.*
2. *Cupressus torulosa.*
3. *Michelia Champaca.*
4. *Semecarpus Anacardium.*
5. *Cedrela Toona.*
6. *Gmelina arborea.*
7. *Ficus bengalensis.*
8. *Boswellia serrata.*
9. *Kydia calycina.*
10. *Pinus excelsa.*
11. *Cedrus Deodara.*
12. *Æsculus indica.*
13. *Michelia excelsa.*
14. *Artocarpus Chaplasha.*
15. *Buchanania latifolia.*
16. *Sterculia alata.*
17. *Bombax insigne.*
18. *Picea Morinda.*
19. *Abies Pindrow.*
20. *Ficus glomerata.*

(vi) *Very light.* *Under 30 lbs.*

1. *Trewia nudiflora.*
2. *Populus ciliata.*
3. *Duabanga sonneratioides.*
4. *Spondias mangifera.*
5. *Bombax malabaricum.*
6. *Ailanthus excelsa.*
7. *Sterculia colorata.*
8. *Tetrameles nudiflora.*
9. *Erythrina suberosa.*
10. *Moringa pterygosperma.*
11. *Sterculia villosa.*
12. *Cochlospermum Gossypium.*

In each of the above classes the separate woods have been arranged as nearly as possible in order of their specific gravity, beginning with the heaviest and ending with the lightest.

SECTION IV.—HARDNESS.

1. *General.*

By the *hardness* of a wood is understood the resistance which it offers to penetration by another body, and to wear and tear in general. It is a desirable quality in woods employed for many purposes, for example sugar and oil mills, cart wheels and axles, tent-pegs, engraving blocks, tool-handles, runners of sledges, etc. Soft wood, on the other hand, is required for rough packing-cases, matches, wood-pulp, etc. The resistance offered to any cutting or other instrument depends on whether the instrument is applied in the direction of the fibres, at right angles to them, or obliquely to them; it also depends on the kind of instrument used. Apart from the action of different tools, which will be considered separately in Chapter III, the hardness of a wood generally depends on one or more of the following five factors:—

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(1) ANATOMICAL STRUCTURE.

Hardness depends on the degree of cohesion of the fibres and on the amount of ligneous matter contained in the tissues of the wood: thus heartwood is harder than sapwood. Wavy or anastomosed fibres usually increase hardness, while shortness of fibre diminishes it.

(2) SPECIFIC GRAVITY.

In the case of dry wood, as a general rule the factors which tend to increase specific gravity also tend to increase hardness. Thus, for example, slow grown coniferous wood is harder than fast grown wood of the same species.

(3) AMOUNT OF MOISTURE.

Dry wood is harder than green wood, partly because in moist wood the quantity of solid matter occupies more space than the same quantity of solid matter in dry wood. For this reason green wood is often used for conversion in preference to seasoned wood where there is no danger of warping or splitting during the subsequent drying. Thus dugouts are made of the green wood of *Duabanga sonneratioides*, which dries without warping or splitting; so the green wood of *Xylia dolabriformis* is usually preferred to dry wood for sawing in Burma, owing to the excessive hardness of the latter. Steaming or boiling wood softens it, but reduces its strength.

(4) AMOUNT OF RESIN.

The hardness of wood is increased by the presence of resin, particularly when the resin is dry and contains little oil. Thus old dry resinous stumps of deodar are very hard, as are the resinous close-ringed knots found in coniferous wood.

(5) SOUNDNESS.

Decay softens wood by disintegrating and destroying the tissues.

2. *Classification of Woods according to Hardness.*

The following is a list of some of the more important Indian woods, given alphabetically in classes arranged according to relative hardness:—

I.—Extremely hard.

1. *Dalbergia latifolia.*
2. *Hardwickia binata.*
3. *Mesua ferrea.*
4. *Pterocarpus santalinus.*
5. *Soymida febrifuga.*
6. *Xylia dolabriformis.*

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I.—*Very hard.*

1. *Acacia Catechu.*
2. *Anogeissus latifolia.*
3. *Cassia Fistula.*
4. *Casuarina equisetifolia.*
5. *Chloroxylon Swietenia.*
6. *Dalbergia Sissoo.*
7. *Diospyros Ebenum.*
8. *Heritiera minor.*
9. *Lagerstrœmia parviflora.*
10. *Melanorrhœa usitata.*
11. *Murraya exotica.*
12. *Pentacme suavis.*
13. *Prosopis spicigera.*
14. *Pterocarpus Marsupium.*
15. *Quercus dilatata.*
16. *Q. incana.*
17. *Q. semecarpifolia.*
18. *Schleichera trijuga.*
19. *Shorea obtusa.*
20. *Terminalia Chebula.*

III.—*Hard.*

1. *Acacia arabica.*
2. *A. leucophlœa.*
3. *Ægle Marmelos.*
4. *Albizzia Lebbek.*
5. *Artocarpus Lakoocha.*
6. *Bassia latifolia.*
7. *Borassus flabellifer* (outer wood).
8. *Buxus sempervirens.*
9. *Chickrassia tabularis.*
10. *Dipterocarpus tuberculatus.*
11. *Hopea odorata.*
12. *Lagerstrœmia Flos-Reginæ.*
13. *Melia indica.*
14. *Ougeinia dalbergioides.*
15. *Pterocarpus indicus.*
16. *P. macrocarpus.*
17. *Santalum album.*
18. *Shorea robusta.*
19. *Tamarindus indica.*
20. *Taxus baccata.*
21. *Terminalia belerica.*
22. *T. tomentosa.*
23. *Zizyphus Jujuba.*

IV.—*Moderately hard.*

1. *Adina cordifolia.*
2. *Artocarpus Chaplasha.*
3. *A. integrifolia.*
4. *Boswellia serrata.*
5. *Buchanania latifolia.*
6. *Careya arborea.*
7. *Cedrus Deodara.*
8. *Cupressus torulosa.*
9. *Dillenia indica.*
10. *Dipterocarpus alatus.*
11. *D. turbinatus*
12. *Eugenia Jambolana.*
13. *Ficus bengalensis.*
14. *Garuga pinnata.*
15. *Juglans regia.*
16. *Odina Wodier.*
17. *Pinus excelsa.*
18. *P. longifolia.*
19. *Pterocarpus dalbergioides.*
20. *Pterospermum acerifolium.*
21. *Schima Wallichii.*
22. *Tectona grandis.*

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V.—Soft.

1. *Æsculus indica.*
2. *Anthocephalus Cadamba.*
3. *Bombax malabaricum.*
4. *Butea frondosa.*
5. *Cedrela Toona.*
6. *Duabanga sonneratioides.*
7. *Ficus glomerata.*
8. *Gmelina arborea.*
9. *Kydia calycina.*
10. *Michelia Champaca.*
11. *M. excelsa.*
12. *Populus ciliata.*
13. *Salix tetrasperma.*
14. *Semecarpus Anacardium.*
15. *Spondias mangifera.*
16. *Sterculia alata.*
17. *Trewia nudiflora.*

VI.—Very soft.

1. *Cochlospermum Gossypium.*
2. *Erythrina* spp.
3. *Moringa pterygosperma.*
4. *Sterculia colorata.*
5. *S. urens.*
6. *S. villosa.*
7. *Wightia gigantea.*

SECTION V.—FLEXIBILITY.

Flexibility in a wood means its capacity for being bent out of shape without breaking, whereas a wood which cannot be bent without breaking is said to be *brittle*. Flexibility is a property required by woods used for sieve-frames, basket-work, bent-wood furniture, planks for the curved sides of ships, etc., the thinner the pieces used the greater being their flexibility. The maximum amount of flexibility is obtained in woods which have long straight fibres and are free from knots, waviness and decay. Soft light woods are more flexible than hard heavy woods, because their loose structure allows the fibres to play one upon the other; hence soft root-wood is more flexible than stem-wood, and sapwood than heartwood. Moisture also increases flexibility, while dryness decreases it. Flexibility is temporarily increased by boiling or steaming, but after the wood has dried again it loses its flexibility and becomes more brittle than it was originally. Steaming is resorted to in the manufacture of bent-wood furniture and in the preparation of flexible planks for the sides of ships, which are nailed on while hot and damp.

Young trees are more flexible than old ones, young coppice shoots being usually more flexible than seedlings: climbers are the most flexible of woody plants owing to their long straight loose fibres. Frost reduces flexibility, rendering wood brittle. Examples of flexibility are to be found in canes and bamboos, the twigs and coppice shoots of willows, *Indigofera*, *Vitex*, *Celtis*, and many other plants, as well as most climbers.

SECTION VI.—ELASTICITY.

Elasticity resembles flexibility to a certain extent in that it implies a capacity for being bent out of the original shape; in addition to this, however, it means the power of *springing back to the original shape*, whereas flexibility implies no such power. Thus whereas a flexible wood need not possess elasticity, an elastic must possess a certain amount of flexibility. Elasticity is a property required by woods used for carriage-shafts, bows, shoulder-poles, spear-shafts, fishing-rods, masts of ships, etc.

Elasticity, like flexibility, is increased by length and straightness of fibre, and freedom from knots, waviness and unsoundness, while it is diminished by frost. In most other cases, however, the factors which increase the flexibility of a wood tend to diminish its elasticity. Thus dryness increases elasticity provided it is not excessive, while moisture decreases it. The presence of resin in small quantity increases elasticity, while much fluid resin diminishes it, and much dry resin tends to make wood brittle. Elasticity, as a rule, increases with specific gravity: thus the heavier wood of the stem is more elastic than the lighter wood of the roots, heartwood is more elastic than sapwood, while slow-grown coniferous wood is more elastic than fast-grown wood. Elasticity is increased by slow seasoning.

The following are examples of some of the more elastic Indian woods, arranged as nearly as possible in order of elasticity :—

I.—**Very elastic.**—*Grewia* spp., *Hardwickia binata*, *Borassus flabellifer*, *Anogeissus latifolia*, *Areca Catechu* (the betel-nut palm), *Mesua ferrea*.

II.—**Elastic.**—*Mimusops Elengi*, *Chloroxylon Swietenia*, *Acacia Catechu*, *Casuarina equisetifolia*, *Hopea odorata*, *Shorea robusta*, *Pterocarpus santalinus, Xylia dolabriformis, Artocarpus Lakoocha, Acacia arabica, Murraya exotica, Albizzia Lebbek, Dalbergia latifolia, Diospyros* spp., *Dalbergia Sissoo, Pterocarpus dalbergioides.*

III.—**Moderately elastic**—*Dillenia indica, Mangifera indica, Lagerstrœmia Flos-Reginæ, Tectona grandis, Michelia excelsa, Mela indica, Cedrus Deodara, Adina cordifolia, Dipterocarpus alatus, Cedrela Toona, Chickrassia tabularis, Eugenia Jambolana, Gmelina arborea.*

Bamboos also possess the property of elasticity in a high degree.

SECTION VII.—FISSIBILITY.

1. *General.*

Fissibility in a wood means the capacity for being split in the direction of the fibres, this splitting being usually effected by means of an axe, a wedge or other similar implement. Fissibility is an important property on which various industries depend, for example the conversion of split fuel, the manufacture of wheel spokes, oars, carriage shafts, cask-staves, basket-work and matting, etc.

2. *Factors influencing Fissibility.*

The main factors which influence the fissibility of wood have recently been made the subject of experiment by the writer in the case of 61 different species of Indian woods, a specially designed splitting machine being employed for the purpose. The results of these experiments show that the chief considerations affecting the ease or otherwise with which wood may be split are as follows:—

(1) ANATOMICAL STRUCTURE OF THE WOOD.

The most important factor affecting the fissibility of wood is its anatomical structure, particularly the straightness or crossness of grain. Woods, whether hard or soft, which have a straight grain, invariably split more easily than those with cross-fibres. Thus straight grained samples of *Acacia Catechu*, one of the hardest of woods, split with comparative ease,

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whereas much softer woods with cross-fibres, such as *Garuga pinnata*, *Bombax malabaricum*, *Cedrela Toona* and others, require more force to split them. In general it may be said that anything which interferes with the straightness of the grain, such as the presence of knots and dormant buds, or obliqueness or waviness of the fibres, reduces the fissibility of wood. The presence of large medullary rays, provided the wood is fairly straight-grained, tends to increase the fissibility of wood in a radial direction.

(2) Hardness.

Hardness has far less influence on the fissibility of a wood than anatomical structure. This is particularly the case with straight-grained woods; thus *Acacia Catechu* and *Homalium tomentosum*, both hard woods with straight grain, split without difficulty. In the case of cross-fibred woods hardness has considerable influence, for in the case of such woods the wedge is driven through the wood by severing the cross-fibres transversely as well as by tearing them out; this process is accomplished more easily in the case of soft woods than in the case of hard woods. Thus hard cross-fibred woods like *Ougeinia dalbergioides*, *Dalbergia latifolia*, *Pterocarpus Marsupium* and *Shorea robusta* are more difficult to split than soft cross-fibred woods such as *Bombax malabaricum*, *Garuga pinnata* and *Oroxylum indicum*. In all these cases, however, the primary cause of difficulty in splitting is the crossness of the grain rather than the hardness of the wood.

(3) Elasticity.

When a wedge is driven into an elastic wood, the wood on either side of the crack pressing on the wedge tends to force the fibres apart some distance in front of it, thus facilitating the work of splitting. In a wood which is not elastic the fibres are forced apart only by immediate contact with the point of the wedge, or, in the case of a brittle wood, are actually broken asunder by it. Hence as a general rule what tends to increase the elasticity of a wood also tends to increase its fissibility, other conditions being equal. These remarks refer mainly to wood which is straight-grained or nearly so. In the case of a very cross-grained elastic wood like *Ougeinia dalbergioides* the stiffness of the tough fibres may cause the wedge repeatedly to spring back out of the cleft.

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(4) DIRECTION IN WHICH THE SPLITTING FORCE ACTS.

European text-books tell us that wood splits more easily in a radial than in a tangential direction. This possibly holds with most European woods, but in the case of Indian woods fission is generally much easier along the tangential than along the radial plane. This applies particularly to cross-grained woods, because cross-grain is normally encountered during radial and not during tangential splitting. Thus in the tests referred to above it was found that in the case of *Dalbergia Oliveri* splitting in a radial direction was more than 17 times as difficult as it was in a tangential direction; in *Ougeinia dalbergioides* it was more than 13 times, in *Pterocarpus Marsupium* more than 12 times, in *Shorea robusta* more than 9 times, and in *Dalbergia latifolia* 7 times. In straight-grained woods the difference is not nearly so marked, the necessary splitting force in some cases being slightly less along the radial than along the tangential plane.

(5) AMOUNT OF MOISTURE.

According to Gayer, European hard woods are more fissile when wet and soft woods are more fissile when dry. This is not borne out by the tests referred to above, for of 16 hard and soft woods tested, all split more easily when dry than when green except one, *Sterculia villosa*, which required the same splitting force for green and dry wood. The explanation why green wood splits with more difficulty than dry wood is no doubt partly that it is less elastic and partly that the moisture toughens the fibres, this latter explanation being corroborated by the fact that the greatest disparity in the relative forces required for splitting green and dry wood exists in cross-fibred woods, where the fibres have to be cut across or torn apart with difficulty, whereas in straight-grained woods the disparity is small or non-existent.

3. *Classification of Woods according to Fissibility.*

A list of woods grouped into classes according to fissibility, as ascertained from the tests already alluded to, is given below. In this list the splitting force for *Taxus baccata*, the most fissile of all the woods given, is taken as unity, and the relative splitting forces of the other classes are given for comparison. In each class the woods are arranged in order of fissibility, as based on the mean between the splitting forces for radial and tangential cleavage.

I.—*Very easy to split.* (Splitting force up to twice that of *Taxus baccata*).

1. *Taxus baccata.*
2. *Sterculia villosa.*
3. *Abies Pindrow.*
4. *Pinus excelsa.*
5. *Tectona grandis.*
6. *Homalium tomentosum.*
7. *Cedrus Deodara.*
8. *Picea Morinda.*
9. *Æsculus indica.*
   Pinus longifolia.
   Spondias mangifera.
   Boswellia serrata.
   Podocarpus neriifolia.
14. *Carallia integerrima.*
15. *Gardenia latifolia.*
16. *Lagerstrœmia tomentosa.*
   Semecarpus Anacardium.

II.—*Easy to split.* (Splitting force twice to 4 times that of *Taxus baccata*).

1. *Populus ciliata.*
   Odina Wodier.
3. *Acacia Catechu.*
4. *Mallotus philippinensis.*
   Albizzia procera.
6. *Oroxylum indicum.*
   Schrebera swietenioides.
8. *Dipterocarpus tuberculatus.*
9. *Cassia Fistula.*
   Buchanamia latifolia.
   Zizyplus xylopyra.
12. *Lagerstrœmia parviflora.*
13. *Gardenia turgida.*
14. *Adina cordifolia.*
15. *Pterocarpus macrocarpus.*
   Berrya Ammonilla.
17. *Kydia calycina.*
18. *Gardenia lucida.*
   Garuga pinnata.
20. *Terminalia belerica.*
21. *Cedrela Toona.*
22. *Terminalia tomentosa.*

III.—*Moderately difficult to split.* (Splitting force 4 to 6 times that of *Taxus baccata*).

1. *Bridelia retusa.*
2. *Grewia vestita.*
3. *Casuarina equisetifolia.*
4. *Quercus semecarpifolia.*
5. *Bombax malabaricum.*
6. *Albizzia stipulata.*
7. *Holoptelea integrifolia.*
   Gmelina arborea.
9. *Anogeissus latifolia.*
   Ægle Marmelos.
11. *Gardenia gummifera.*
12. *Quercus dilatata.*

IV.—*Difficult to split.* (Splitting force 6 to 10 times that of *Taxus baccata*).

1. *Dalbergia Sissoo.*
2. *Pterospermum acerifolium.*
   Calophyllum spectabile.
4. *Shorea robusta.*
5. *Chloroxylon Swietenia.*
6. *Pterocarpus Marsupium.*

V.—*Very difficult to split.*		(Splitting force more than 10 times that of *Taxus baccata*).
1.	*Bauhinia retusa.* *Dalbergia latifolia.*	(12 times as difficult to split as *Taxus baccata.*)
3.	*Dalbergia Oliveri.*	(16 times as difficult to split as *Taxus baccata.*)
4.	*Ougeinia dalbergioides.*	(38 times as difficult to split as *Taxus baccata.*)

Of the samples of woods tested all those in classes IV and V were cross-grained, and all those in class I were straight-grained except *Lagerstrœmia tomentosa*, which was slightly cross-grained. In the other classes the grain varied.

SECTION VIII.—STRENGTH.

1. *General.*

By the *strength* of a wood is understood its resistance to (1) *tension*, (2) *crushing*, (3) *shearing*, (4) *torsion*, and (5) *transverse strain*. A description of the methods of testing the various kinds of strength in timber belongs to the province of Applied Mechanics, and cannot be undertaken here: we are concerned rather with the properties of timber which influence its strength, and the uses to which woods possessing one or other form of strength are put. In all cases the strength of timber is directly proportional to its soundness, and the following remarks on the various kinds of strength refer to sound timber only :—

2. *Resistance to Tension.*

The strength of a wood in resisting tensile strains, that is forces acting in opposite directions and tending to pull the fibres of the wood apart, is called its tenacity. This tenacity is greatest in the direction of the grain, and in woods whose fibres are long and straight. It is diminished by steaming or boiling, and by continued moisture, but not by temporary wetting. Tenacity across the grain is much less in conifers and other soft woods than in harder woods. In actual practice wood is seldom called on to exert its greatest strength in resisting tensile strains, except in certain special cases, as in suspension bridges where the ropes are made of twigs; for example in the Punjab Himalayas bridges are made up of the tough twigs of *Parrotia Jacquemontiana*

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twisted together into thick ropes. Tensile strength is a property required by all fibres used in rope-making.

3. *Resistance to Crushing.*

This is the opposite of resistance to tension; it is greatest in the direction of the fibres, depends largely on the lateral adhesion of the fibres, and is therefore reduced by moisture. Crushing across the grain takes place with a kind of shearing or sliding. Crushing strength is required in timber used for posts and piles supporting great weight, wheel-spokes, etc., but in actual practice it is seldom called into account, because in such cases as a post supporting a heavy weight the post usually bends and breaks before it is crushed by the weight. Resistance to crushing generally varies with the hardness of the wood; thus the crushing strength of *Mesua ferrea* and *Pterocarpus santalinus* is twice that of teak and about four times that of *Bombax malabaricum.* The crushing strength of dry timber varies from ½ to ⅔ of its tenacity.

4. *Resistance to Shearing.*

This means the strength which resists the separation of the fibres by sliding away from each other, and is exemplified in woods used for purposes where they are subjected to much hammering or other wear and tear, for example piles, tent pegs, chisel handles, mallets, etc. It is greatest in the direction of the fibres, depends on the cohesion of the fibres, and varies largely, but not entirely, with the hardness of the wood. Among Indian woods some of the most resistant to shearing strains are *Pterocarpus santalinus*, *Murraya exotica*, *Mimusops Elengi* and *Sapindus trifoliatus.*

5. *Resistance to Torsion.*

This is the resistance offered by a piece of wood to a couple of forces tending to twist the wood in opposite directions, as for example in capstans, windlasses, oil and sugar rollers, cart-axles, etc.; it is of little practical importance, as the dimensions of the pieces of wood used can generally be made such that resistance to torsion need not fail.

6. *Resistance to Transverse Strain.*

This resistance, usually known as *transverse strength*, is the most important form of strength in timber, being the strength required by beams, rafters, steps of ladders, axle-trees, cart-yokes and for many other purposes where wood is subjected to a transverse force which tends to break it. Transverse strength is increased by length and straightness of fibre and by uniformity of structure : thus the presence of knots and other flaws in timber reduces its strength. The degree to which wood has been seasoned has an important bearing on its strength, seasoned wood being considerably stronger than green wood. The United States Forest Department have discovered that the relation of moisture to strength follows a definite law, and that air-dried wood protected from the weather and containing 12 per cent. of moisture is 1·7 to 2·4 times stronger than green wood. Generally whatever tends to increase the elasticity of a wood also tends to increase its strength. Wood which has been slowly seasoned is stronger than quickly-seasoned wood ; hence the wood of a tree killed by girdling is weaker than that of a tree which has been felled green and slowly seasoned.

As woods of one and the same species frequently differ very greatly in transverse strength, some specimens having more than double the strength of others of the same species, any list of timbers in order of strength can only be approximately correct. For example in *sál* timber the value of P* varies from 300 to 900 ; variation to such an extent is, however, unusual, and may be due in particular cases to differences in moisture conditions or to structural causes such as the presence of defects, etc. Locality also has considerable influence on the transverse strength of wood.

In the list given below some of the commoner or more important Indian woods are classified according to the average value of P, those in each class being arranged as nearly as possible in order of transverse strength.

(i) *P = 1,000 and over.*

1. *Xylia dolabriformis* (Burmese).
2. *Pterocarpus macrocarpus.*
3. *Mesua ferrea.*

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* P is the coefficient of transverse strength, obtained from the formula $P = \frac{W \times L}{B \times D^2}$, where W is the smallest weight in lbs., which, placed on the middle of a bar of wood supported at either end, causes it to break, L is the length of the bar between supports, in feet, B is the breadth of the bar in inches, and D its thickness in inches. Transverse strength may also be expressed in tons per square inch.

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(ii) *P*=900 to 1,000.

1. *Schleichera trijuga.*
2. *Hardwickia binata.*
3. *Chloroxylon Swietenia.*
4. *Homalium tomentosum.*
5. *Dalbergia latifolia.*
6. *Heritiera minor.*

(iii) *P*=800 to 900.

1. *Acacia arabica.*
2. *Borassus flabellifer.*
3. *Pterocarpus santalinus.*
4. *Berrya Ammonilla.*
5. *Ougeinia dalbergioides.*
6. *Soymida febrifuga.*
7. *Dalbergia Sissoo.*
8. *Terminalia tomentosa.*

(iv) *P*=700 to 800.

1. *Shorea robusta.*
2. *Albizzia Lebbek.*
3. *Anogeissus latifolia.*
4. *Hopea odorata.*
5. *Quercus semecarpifolia.*
6. *Shorea obtusa.*
7. *Dipterocarpus tuberculatus.*
8. *D. alatus.*
9. *Lagerstrœmia Flos-Reginæ.*
10. *Cassia Fistula.*

(v) *P*=600 to 700.

1. *Artocarpus integrifolia.*
2. *Dillenia indica.*
3. *Pterocarpus Marsupium.*
4. *Pinus longifolia.*
5. *Carallia integerrima.*
6. *Grewia tiliæfolia.*
7. *Lagerstrœmia tomentosa.*
8. *Xylia dolabriformis* (Indian).*
9. *Lagerstrœmia lanceolata.*
10. *Pterocarpus dalbergioides.*
11. *Tectona grandis.*
12. *Chickrassia tabularis.*
13. *Lagerstrœmia parviflora.*
14. *Michelia Champaca.*
15. *Mangifera indica.*
16. *Eugenia Jambolana.*

(vi) *P*=under 600.

1. *Bombax malabaricum.*
2. *Adina cordifolia.*
3. *Schima Wallichii.*
4. *Odina Wodier.*
5. *Melanorrhæa usitata.*
6. *Gmelina arborea.*
7. *Cedrela Toona.*
8. *Cedrus Deodara.*
9. *Spondias mangifera.*
10. *Butea frondosa.*

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* Recent investigations, as yet incomplete, tend to show that the Indian tree is a different species from the Burmese one.

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SECTION IX.—SEASONING POWER, AND LIABILITY TO BE AFFECTED BY MOISTURE.

1. *Seasoning.*

(1) PERCENTAGE OF WATER IN WOOD.

Before it can be used for most purposes, wood requires to be made thoroughly air-dry : when in this condition it is said to be seasoned. Even well-seasoned wood contains a certain proportion of water which can be expelled only by artificial drying in hot air ; the percentage of water in seasoned wood depends largely on the species and on the humidity of the atmosphere for the time being.

Experiments made by the writer with a large number of Indian woods show that as a general rule the proportion of moisture in air-dry wood varies from 9 to 16 per cent. by weight, while that of green wood varies from 30 to 60 per cent. As a general rule the harder woods were found to contain a smaller percentage of water than the softer woods. Thus hard woods showed percentages as follows: *Acacia Catechu*, 30% ; *Schleichera trijuga*, 33% ; *Quercus incana* and *dilatata*, 34% ; *Q. semecarpifolia*, 35 % ; *Dalbergia Sissoo*, 36 % ; *Ougeinia dalbergioides*, 40% ; *Shorea robusta*, 41 %. Soft woods on the other hand as a rule showed higher percentages, the following being a few examples : *Buchanania latifolia*, 49 % ; *Ficus retusa*, 50 % ; *Spondias mangifera*, 54 % ; *Garuga pinnata*, 55% ; *Bombax malabaricum*, 57% ; *Ficus religiosa*, 60 %. It is generally supposed that in living or freshly felled trees the proportion of water in the sapwood exceeds that in the heartwood. In the course of these tests, however, it was found that in the majority of cases the percentage of water in the heartwood was greater than in the sapwood.

(2) RAPIDITY OF SEASONING.

The rate of drying does not always take place uniformly throughout a log. Usually wood dries most quickly just after being cut, subsequent drying taking place more slowly. The rapidity with which a wood dries depends on several circumstances, of which the following are the most important :—

(*a*) *Structure and nature of the wood.*—Porous woods season more quickly than close-grained woods. Sapwood dries more quickly than heartwood.

(*b*) *Wood surface exposed.*—The greater the extent of wood surface exposed in proportion to the volume of the wood, the quicker will the seasoning be : thus seasoning is hastened by sawing wood into thin planks. For the same reason a log which has been barked seasons more quickly than a log with the bark on. Wood seasons most rapidly on a transverse section and least rapidly on a longitudinal tangential section. It stands to reason that a large log or piece of wood will take longer to season than a small one.

(*c*) *Condition of the air and locality.*—Seasoning is slow in a damp cool atmosphere, in a place closed to free access of air, and where the wood is placed on damp ground, whereas it is rapid in a dry warm atmosphere with a free current of air, and where the wood is raised off the ground. Seasoning is quicker under cover than in the open, provided there is free circulation of air.

(*d*) *Method of seasoning.*—There are various methods, described below, of hastening the seasoning of wood. Steaming or boiling followed by drying causes rapid seasoning ; some methods of impregnation with antiseptic substances are said to retard it, others to hasten it. Timber which has been floated and then dried seasons more rapidly than timber which has not been placed in water, while seasoned wood when placed in water and afterwards again dried, takes a shorter time to dry again than green wood which has been similarly dealt with.

(*e*) *Species of timber.*—Some woods season completely in a year, but others take many years. *Sál*,

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for example, may not be completely seasoned after 10 years; it dries quickly on the outside, but the inside remains moist for a long time.

2. *Moisture in Relation to Wood.*

(1) GENERAL ACCOUNT.

The rate of absorption of moisture by seasoned wood depends generally on the same circumstances as the rapidity of seasoning: that is, the longer a wood takes to season the more slowly does it afterwards absorb moisture. The absorption of moisture becomes an important matter in cases where a wood requires to be as watertight as possible, for example wood required for wine-cask staves. In Europe these are made of oak, and it has been found by experience that the timber should be felled in winter, that is, in the season of rest, and not in spring, when the wood is more porous, and considerable loss of wine is liable to occur through leakage. In floating operations also the rapid absorption of water may become a serious obstacle, floating timber becoming saturated, or, as it is usually termed, "waterlogged," and sinking. In the Himalayas the floating of spruce, silver fir, *Alnus nitida* and *Juglans regia* for long distances is for this reason attended with risk: deodar and *Pinus excelsa*, on the other hand, do not easily become waterlogged. Unsound wood absorbs moisture quickly.

(2) SHRINKING AND SWELLING.

During seasoning wood loses volume and shrinks, while if it is placed in water or in a moist atmosphere it swells by the absorption of water. Shrinkage is greater the larger the quantity of moisture originally in the green wood. There is least shrinkage in the direction of the fibres, that is longitudinally, and most in a tangential direction; hence the advisability of cutting planks in a radial rather than in a tangential direction.

Shrinkage is greatest in a dry warm atmosphere.

(6) WARPING.

When shrinkage of wood takes place more in some parts than in others, and not evenly throughout, the wood bends or "warps." The extent of warping depends chiefly on the following considerations :—

(*a*) *Grain of the wood.*—Woods with even grain, and with tissues regularly distributed, warp less than uneven-grained wood : for this reason planks cut in a radial direction warp less than planks cut in a tangential direction, as in the former case the annual rings are regularly distributed along the plank, and do not traverse it at various angles. The wood of trees grown in the open, and thus having irregularly shaped boles, warps more than that of straight clean forest-grown trees. The timber of trees with twisted fibres is apt to warp badly.

(*b*) *Part of the tree.*—Planks cut near the centre of a log warp less than those cut some distance from the centre. Sapwood warps more than heartwood, young wood more than old wood, and branch-wood more than stem-wood.

(*c*) *Species of tree.*—Different woods vary greatly in the extent to which they warp, some seasoning well without any tendency to warp and others warping in spite of all precautions. Some examples of each class are given below.

(*d*) *Atmospheric influences.*—Wood subjected to severe extremes of humidity and temperature is more liable to warp than wood kept under more equable conditions. Thus the wood of external plank walls exposed alternately to rain and to severe sun on the outside, while the inside remains more or less protected, is very liable to warp. Similarly, boards lying on damp ground, and exposed to sun and dry air above, warp and bend up at the ends.

Prevention of warping.—Where warping is feared, timber should be seasoned well before cutting it into scantlings, and the scantlings should be allowed to season further before use ; they should be stacked flat one upon another on a perfectly level site and weighted on the top to keep them flat. Equal drying tends to prevent warping : hence the advisability of having all sides of the timber equally exposed to the air, turning it over from time to time if necessary.

If required for fine work the scantlings may be stacked vertically, by standing them on end, and kept moist for two or three months by frequently pouring water on them from above. English shipwrights cut their seasoned logs into scantlings of the required size and shape and leave them to season further for a year before using. Warping may be minimized by steaming or by soaking in or impregnating with oil. The warping of tables, doors, lids of boxes, etc., is prevented by constructing them of more than one piece of wood, the pieces being joined so that the grain of the wood should not lie entirely in one direction.

(4) CRACKING AND SPLITTING.

While wood dries it is frequently apt to crack and split through shrinkage. The extent of this cracking depends on a variety of circumstances, of which the principal are as follows :—

(*a*) *Extent of shrinkage.*—Woods which shrink much are usually most apt to crack and split.

(*b*) *Rapidity of seasoning.*—Rapid seasoning increases liability to crack and split. Hence wood felled in the dry season is more apt to split than wood felled in the rains : the removal of bark before seasoning also increases the danger of splitting.

(*c*) *Size and shape of logs.*—The tendency to split and crack increases with the size of the log and the thickness and breadth of scantling. Round timber splits more readily than timber which has been roughly squared.

(*d*) *Structure of wood.*—Want of uniformity of structure increases the liability to split. Cracks occur most in the radial direction, while in scantlings sawn through the heart, cracks in the direction of the annual rings are often found near the pith.

(*e*) *Species.*—Some species are more liable to crack and split than others : examples are given below.

Prevention of cracking and splitting.—Generally speaking whatever tends to lessen the rapidity of seasoning also tends to prevent cracking ; hence a good safeguard in the case of wood felled in the dry season is to keep it covered with damp straw until the rains, when the danger of splitting is less. Another preventive, particularly in the case of scantlings and sleepers, is to cover them with sawdust. Large cracks are prevented by rough squaring logs and leaving a strip of bark at each corner. Too rapid evaporation at the ends of logs or scantlings, which results in the formation of cracks, may be prevented by smearing the ends with crude earth-oil, or with a thick layer of cowdung, or with tar over which a sheet of tough brown paper is pressed. Other special methods of preventing the formation of cracks are to bore a fair-sized hole up the centre of the log, or to saw it through longitudinally along one radius from the periphery to the centre, as is done with billets of boxwood in Jaunsar, or to nail S-shaped clamps on the ends of the log where cracks are feared. Steaming followed by slow drying prevents the formation of large cracks.

3. *Methods of Seasoning Wood.*

There are various methods of seasoning timber, of which the following are the principal :—

(1) Natural seasoning.

(2) Water seasoning—

   (*a*) In fresh water.

   (*b*) In salt water.

(3) Artificial seasoning.

The natural method is the one most generally employed, though in the case of timber floated for some distance seasoning is assisted by the immersion in water.

(1) NATURAL SEASONING.

This consists of exposing the wood to the drying action of the atmosphere without employing any artificial means of extracting the moisture from it. Timber should be allowed to season evenly and not too rapidly, and should therefore be placed in an airy situation, raised above the damp ground, and not exposed to sun and rain. In actual practice logs are frequently left lying in the forest for some time, and become partly seasoned there ; in this case exposure to strong sun and rain alternately should be avoided as much as possible by placing the logs in a shady place, and the logs should be turned over occasionally.

Scantlings should be sawn from seasoned or partly seasoned logs and should themselves be left to season further before use. The barking of logs hastens seasoning, but may induce cracks; it is, however, a necessary precaution where unbarked logs are liable to insect attacks, especially if the logs have to be left lying in the forest for some time. In Burma teak trees are killed by girdling three years before felling, in order to render the timber light enough to float; in these three years the timber thus becomes fairly well seasoned before the tree is felled. Firewood should be seasoned as rapidly as possible, and should therefore be cut and stacked in the dry weather. Further details on the stacking of timber and firewood for seasoning purposes will be found on pages 145 to 147.

(2) WATER SEASONING.

(*a*) *Fresh water.*—The method of water seasoning is a common one, its chief advantages being that it shortens the time required for subsequent drying, promotes more even seasoning, and in the case of soft white woods prevents the discoloration which frequently takes place when the wood is air-seasoned in the log. In water-seasoning green timber is entirely immersed in fresh water for a period of time which may vary from 2 weeks to 6 months; it is then taken out of the water and subjected to the process of natural seasoning already described, the time required for seasoning being shortened by the immersion in water, which should be complete and not partial. The water should, if possible, be running water, stagnant pools being avoided. If the logs have to be kept in a tank they should be barked to prevent discoloration of the water. Green scantlings may be immersed in running water for two weeks and then dried quickly by stacking them vertically in an airy place: they will then be ready for use in about a month. The scantlings should be completely immersed in the water, being tied down or weighted if need be. Teak, *Sál*, *Dalbergia latifolia* and *Terminalia belerica* are said to improve by lying in water.

(*b*) *Salt water.*—Seasoning in sea water has been practised from time to time, but opinions differ as regards its efficacy: it is certain, however, that the hygroscopic nature of the salt which impregnates the timber during immersion renders it objectionable for many purposes. Timber for ship-building is sometimes so treated before use, but such timber is said

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never to become perfectly dry, while it corrodes iron bolts driven into it. Nevertheless if a ship has had its timber well soaked in salt water it is allowed an extra year's duration in its class when registered at Lloyd's, on the ground that timber so treated is more durable than ordinary timber. It is perhaps unnecessary to mention the danger attending the storage of timber in salt water infested with the *Teredo* and other boring animals. A Japanese method of seasoning timber in salt water is to store it in ponds artificially made near the mouths of streams in such a way that salt and fresh water can both be admitted, in the proportion of 6 parts of the former to 4 of the latter, the admission of the fresh water preventing the attacks of marine borers.

(3) ARTIFICIAL SEASONING.

There are many methods of artificially causing the rapid seasoning of wood, but most of them are of little importance in India and often have little to recommend them; a detailed description of them is therefore unnecessary. The chief of these methods are (*a*) drying in a current of hot dry air, (*b*) extraction of sap by means of a vacuum, (*c*) boiling or steaming followed by drying, (*d*) drying over a smoky fire, (*e*) charring the outside of logs by fire, (*f*) packing wood in common salt, which, being highly hygroscopic, extracts the moisture from the wood; this is employed chiefly for finer woods, (*g*) seasoning by electricity, a somewhat recent French invention whereby the moisture is rapidly driven out of wood by electricity, its place being taken by an antiseptic substance, (*h*) seasoning during antiseptic treatment (see pages 288 to 297).

4. *The Seasoning Properties of various Woods.*

The seasoning properties of woods vary greatly according to species: in this connection the following remarks apply to Indian woods:—

(1) *Woods which season well.*—Many Indian timbers season fairly quickly with comparatively little warping and splitting, a few examples being *Acacia Catechu*, *Albizzia Lebbek*, *Bombax malabaricum*, *Calophyllum spectabile*, *Cedrus Deodara*, *Dalbergia latifolia*, *D. Sissoo*, *Duabanga sonneratioides*, *Gmelina arborea*, *Pinus*

excelsa, Podocarpus neriifolia, Pterocarpus dalbergioides, P. macrocarpus, P. Marsupium, Tectona grandis.

(2) *Woods liable to warp and split.—Adina cordifolia Anogeissus acuminata, A. latifolia, Bischofia javanica, Butea frondosa, Casuarina equisetifolia, Cedrela Toona, Dillenia pentagyna, Diospyros Kurzii, Mesua ferrea, Miliusa velutina, Phyllanthus Emblica, Quercus* spp., *Rhododendron arboreum, Schima Wallichii, Shorea robusta, Terminalia tomentosa.*

(3) *Woods liable to warp.—Chickrassia tabularis, Dipterocarpus tuberculatus, Dysoxylum malabaricum, Eugenia Jambolana, Taxus baccata.*

(4) *Woods liable to split.—Hardwickia binata, Homalium tomentosum, Mimusops hexandra, Schleichera trijuga, Terminalia Arjuna, Xylia dolabriformis.*

(5) *Woods liable to shrink.—Abies Pindrow, Heritiera minor, Pinus longifolia, Quercus* spp., *Schima Wallichii.*

(6) *Woods liable to discoloration.*—Many soft whitish woods are liable to discoloration if dry-seasoned in the log, and should therefore be converted green in order to obtain white planks. Experiments with *Bombax malabaricum* show that this wood remains white in the log for months if kept in water, and the same treatment would probably have a similar effect in the case of other woods. The following are some examples of woods which become discoloured in this way :—*Ailanthus excelsa* (*slightly*), *A. malabarica, Alstonia scholaris, Bombax malabaricum, Boswellia serrata, Buchanania latifolia, Dalbergia lanceolaria, Elæocarpus lanceæfolius* (*slightly*), *Evodia fraxinifolia* (*slightly*), *Excæcaria Agallocha, Garuga pinnata, Givotia rottleriformis, Harpullia cupanioides, Heptapleurum elatum, Kydia calycina, Mallotus philippinensis, Odina Wodier* (*sapwood*), *Semecarpus Anacardium, Spondias mangifera, Tetrameles nudiflora, Trewia nudiflora.*

SECTION X.—DURABILITY.

1. *General Account.*

By durability is understood the power of a wood to withstand decay and the attacks of insects and other forms of animal life ; it is usually measured by the length of time a piece of wood will remain immune from attack.

Decay or *rot* in timber is caused by certain fungi gaining admittance by means of spores which germinate and send out minute thread-like *hyphæ* ; these hyphæ, which become massed together into a felt-like *mycelium*, eat into the wood, breaking down the cell-walls and disintegrating the tissues, the wood becoming, in popular language, decayed or rotten. The term *dry rot* is applied to the rot caused in timber by certain species of fungi, of which the most important is *Merulius lacrymans.* Dry rot is recognized by a change in the colour of the wood, a dull sound when the wood is struck, decrease of specific gravity owing to loss of substance, the peculiar odour of decaying wood, and cracking and warping of the timber owing to the shrinking of the tissues attacked ; the wood becomes soft, being easily cut with a knife when wet, and when dry being friable and easily crushed to powder in the fingers ; finally, the mycelium of the fungus can be detected within the wood and possibly the sporophores will be found on the outside.

Insects and other animals. We are concerned here only with insects which affect the durability of timber, and need not therefore consider insects which bore into living trees or fresh-felled wood ; these may be regarded rather as one of the causes of defects in timber, and will be dealt with in Section XIII of this Chapter.

The insects which test the durability of timber most severely in the tropics are undoubtedly the termites, or so-called white-ants, which destroy all but the most durable timbers. Much damage is also done by beetles, chiefly belonging to the bostrichid and scolytid families, which bore into many of the less durable woods employed in interior work. Bamboos are also subject to their attacks, the familiar "shot-borers" being represented in India by many species, some of the principal being *Dinoderus pilifrons, D. minutus, Bostrichus parallelus,* and *Sinoxylon anale,* all

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bostrichid beetles. The anobiid beetles, so destructive in Europe, have not been observed to any extent in India.

Among marine animals the most destructive is the mollusk *Teredo navalis*, which bores into timber employed for harbour-works, ship-building, and other purposes where the wood is in contact with salt water. There are few woods which can resist the attacks of these creatures, which do incalculable damage, completely destroying all timber structures within their reach in a short space of time, which may vary from a few months to a few years. This animal is commonest in warm climates, but extends into cold latitudes. *Fagrœa fragrans* is said to be capable of withstanding the teredo. Twenty-five logs of *Terminalia tomentosa* were taken up a short time ago from the foundation of Mormugao breakwater on the Bombay coast, where they had lain for 20 years in the sea; they were found to be quite untouched by the teredo, and the wood had become extremely hard.

Tests have recently been carried out in the Lower Godavari District, Madras, to ascertain the powers of various woods in resisting teredo attacks, but none of the woods tried were found to be immune from attack; the woods tested were *Acacia arabica*, *A. Catechu*, *Albizzia Lebbek*, *A. odoratissima*, *Bassia latifolia*, *Chloroxylon Swietenia*, *Dalbergia latifolia*, *Dillenia pentagyna*, *Diospyros Melanoxylon*, *Eugenia Jambolana*, *Gmelina arborea*, *Mangifera indica*, *Mimusops hexandra*, *Pterocarpus Marsupium*, *Schleichera trijuga*, *Soymida febrifuga*, *Stephegyne parvifolia*, *Tamarindus indica*, *Terminalia tomentosa*, and *Xylia dolabriformis*. In Tenasserim experiments made with bamboos placed in the sea and in tidal water showed that whilst all the species tried ultimately succumbed to the teredo, their powers of resistance varied. Teak is slightly attacked, and other woods which are capable of resisting white-ants are not proof against the teredo. The only certain preventive of teredo boring is to coat the timber with copper sheets, concrete, earthenware pipes, or other forms of sheathing, wherever it is in contact with the sea water. Where timber is stored in sea-ports it should not be kept in salt water; if it is desirable to keep it in water at all fresh water should be admitted into the storage tanks until the salinity of the water has been reduced sufficiently to prevent the teredo from living in it.

Among other marine animals destructive to timber may be mentioned various other species of teredo, and certain small crustaceans. In Burma teak timber stored in brackish tidal water is liable to be attacked by the boring mollusk *Martesia fluminalis*, which, however, has not been observed to burrow more than about one inch deep, though this is sufficient to destroy the utility of the outer layers of the timber; the storage of teak timber in brackish water, therefore, is not advisable.

2. *Factors on which Durability depends.*

The durability of timber, assuming it to be sound when felled, depends on a variety of circumstances, as follows:—

(1) THE NATURE OF THE WOOD.

(*a*) *Presence of sap.*—The presence of sap and nutritive material reduces the durability of wood: hence sapwood is less durable than heartwood. The seasoning of wood, thus getting rid of the sap, greatly increases its durability. A tree usually contains least nutriment in its wood just when its new flush of leaves is sent out; the most suitable time to fell trees, therefore, with a view to obtaining the most durable timber, and apart from all other considerations, would be the beginning of the growing season.

(*b*) *Specific gravity and hardness.*—Although many of the heavier and harder woods are very durable, it does not follow, in the case of different species, that the durability of a wood is proportional to its specific gravity or hardness; in one and the same species, however, this does hold, the harder and heavier the wood is the greater being its durability. The harder portions of a piece of wood are the most durable: thus we find the more lignified fibres of many timbers left untouched by white-ants, the softer intervening tissues being destroyed. In conifers the hard autumn-wood is more durable than the soft spring-wood, while in palms the hard outer wood lasts a long time after the soft interior has become decayed or destroyed by white-ants. In the case of one and the same species a dark heartwood usually signifies greater durability than a lighter heartwood, provided the colour is not caused by decay.

(*c*) *Presence of resin, oils, etc.*—Woods are rendered durable by the presence of resin in quantity. The durability of the wood of *Artocarpus Lakoocha*, which resists white-ants, is due to a resinous substance in the wood. Some species, notably teak and deodar, are naturally impregnated with an antiseptic oil which renders them among the most durable of woods. Certain woods contain acrid or bitter salts which prevent them from being attacked by white-ants, for example, *Capparis aphylla*, *Michelia Champaca*, *Melia indica*, and *Salvadora* spp.

(*d*) *Age of tree.*—The wood of middle-aged trees is usually more durable than that of over-mature trees, which frequently has incipient decay in it before the trees are felled.

(2) TREATMENT OF THE WOOD AFTER FELLING.

Wood left lying on the ground for some time in the forest, and exposed to alternate sun and rain, is far more liable to decay than if it is taken at once to a dry shed and seasoned in the proper way.

(3) USE TO WHICH THE WOOD IS PUT.

(*a*) *Wood used in dry place.*—Wood always kept in a comparatively dry place, for example in the interiors of houses in dry climates, and away from damp masonry, is not subject to decay, but is nevertheless liable to the attacks of white-ants and boring insects. Moisture encourages decay, the ends of beams let into damp masonry being particularly subject to dry rot.

(*b*) *Under water.*—Most woods last for a long time when completely immersed in water other than sea water infested with marine worms, provided the water is not flowing with such rapidity as to wear away the wood. Many woods which have little durability when exposed to the air last fairly well under water, for example, *Bombax malabaricum*, *Butea frondosa*, *Erythrina* spp., *Ficus* spp., especially *F. glomerata*, and *Phyllanthus Emblica* : of woods which do not last well under water the best known are *Anogeissnus latifolia* and *Schleichera trijuga*.

(*c*) *Alternations of damp and dryness.*—Decay is greatly favoured by alternations of damp and dryness, particularly in warm climates.

(*d*) *In or on the ground.*—Wood embedded in the ground decays rapidly. In porous soils, where air is easily admitted and alternations of moisture and dryness take place readily, decay is more rapid than in stiff soils. The presence of organic matter greatly encourages decay. Timber buried

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deep in the ground lasts longer than that buried near the surface, where white-ants are most prevalent and rot is better able to attack the wood. In mines, cellars, and other damp places with little ventilation, wood is particularly liable to decay. In timber partly in the ground and partly out of it, most decay usually takes place at the ground level, where there is much alternation of wetting and drying. Similarly, wood lying on the ground is very liable to decay; thus wood for railway sleepers is more severely tried than wood employed for most other purposes, especially when the sleepers are embedded in badly drained or dirty ballast.

3. *Methods of Increasing the Durability of Timber.*

Assuming that timber is sound when felled, and this depends largely on suitable sylvicultural methods, its durability can be greatly enhanced if certain precautions be taken: these are as follows:—

(*a*) Only heartwood should be used where durability is desired, sapwood being removed.

(*b*) Only thoroughly seasoned wood should be employed; there is nothing more conducive to dry rot than the employment of unseasoned timber.

(*c*) The ends of beams should not be embedded in damp masonry. When beams have to come in contact with masonry there should be a space for complete circulation of air round their ends, or the ends of the beam should have metal coverings or should be laid on bed plates. The lime used in the masonry should be thoroughly slaked, as quicklime injures the timber.

(*d*) Timber infected with dry rot should never be stored near sound timber; the affected portions should be cut out and burnt.

(*e*) There are various artificial methods of increasing the durability of timber by antiseptic treatment; some of these methods are described in Part IV. Tarring, coating with paint, or charring by fire are to a certain extent useful, but are not to be relied on; charring to be effective should be deep, and this weakens the timber. To preserve bamboos from attack by boring beetles they should be placed in water as soon after cutting as possible to prevent the ingress of the beetles; to preserve them more permanently they should be soaked in water for 5 days and then dried for several days under cover, after which they should be immersed in crude Rangoon oil for 48 hours. If bamboo-work on houses be well smeared with crude Rangoon oil every year, it lasts longer than bamboo-work not so treated; gurjan oil is also employed for this purpose.

There is a current belief that bamboos felled at the time the moon is full or nearly full are more liable to the attacks of beetle than bamboos felled during the dark phases of the moon; the accuracy or otherwise of this belief has, however, not yet been satisfactorily demonstrated.

4. *Classification of Woods in Order of Durability.*

As the durability of different woods varies much according to the uses to which they may be put, it is impossible to classify woods in a manner which will fulfil all conditions: the following classification, in which the woods in each class are arranged alphabetically, is therefore only an approximate one:—

(i) *Extremely durable.*

1. *Acacia Catechu.*
2. *Fagræa fragrans.*
3. *Hardwickia binata.*
4. *Mesua ferrea.*
5. *Tectona grandis.*
6. *Xylia dolabriformis.*

(ii) *Very durable.*

1. *Artocarpus hirsuta.*
2. *Artocarpus Lakoocha.*
3. *Berrya Ammonilla.*
4. *Cassia Fistula.*
5. *Cedrus Deodara.*
6. *Chloroxylon Swietenia.*
7. *Cupressus torulosa.*
8. *Dalbergia latifolia.*
9. *Dalbergia Sissoo.*
10. *Heritiera minor.*
11. *Hopea odorata.*
12. *Hopea parviflora.*
13. *Lagerstræmia Flos-Reginæ.*
14. *Lagerstræmia lanceolata.*
15. *Michelia Champaca.*
16. *Michelia excelsa.*
17. *Pentacme suavis.*
18. *Pterocarpus dalbergioides.*
19. *Pterocarpus macrocarpus.*
20. *Pterocarpus Marsupium.*
21. *Shorea obtusa.*
22. *Shorea robusta.*
23. *Soymida febrifuga.*

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(iii) *Durable.*

1. *Acacia arabica.*
2. *Adina cordifolia.*
3. *Albizzia Lebbek.*
4. *Albizzia procera.*
5. *Careya arborea.*
6. *Dipterocarpus tuberculatus.*
7. *Eugenia Jambolana.*
8. *Gmelina arborea.*
9. *Lagerstrœmia tomentosa.*
10. *Melia indica.*
11. *Miliusa velutina.*
12. *Ougeinia dalbergioides.*
13. *Pinus excelsa.*
14. *Schima Wallichii.*
15. *Terminalia tomentosa.*

(iv) *Fairly durable.*

1. *Abies Pindrow.*
2. *Anogeissus latifolia.*
3. *Cedrela Toona.*
4. *Dillenia pentagyna.*
5. *Dipterocarpus alatus.*
6. *Dipterocarpus turbinatus.*
7. *Mangifera indica.*
8. *Odina Wodier.*
9. *Picea Morinda.*
10. *Pinus longifolia.*
11. *Quercus* spp.
12. *Schleichera trijuga.*
13. *Terminalia belerica.*
14. *Terminalia Chebula.*

(v) *Slightly durable.*

1. *Bombax malabaricum.*
2. *Boswellia serrata.*
3. *Butea frondosa.*
4. *Erythrina suberosa.*
5. *Ficus* spp.
6. *Spondias mangifera.*
7. *Trewia nudiflora.*

(vi) *Perishable.*

1. *Cochlospermum Gossypium.*
2. *Dalbergia paniculata.*
3. *Moringa pterygosperma.*
4. *Sapium insigne.*
5. *Sterculia* spp.

SECTION XI.—COMBUSTIBILITY AND HEATING POWER.

1. *General Account.*

By the *combustibility* of a wood is meant the readiness with which it catches fire, and having caught fire continues to burn until only ash remains. The *heating power* of a wood is the quantity of heat emitted by a given weight of wood during the process of combustion. When a wood burns, its carbon and hydrogen unite with the oxygen of the air and pass off as carbon dioxide and water vapour, whilst the inorganic elements present in the wood remain behind as incombustible ash. The conditions which affect the combustibility of a wood do not always affect its heating power in the same way, but the two properties may nevertheless be considered together and compared or contrasted as the case may be: the chief of these conditions are as follows:—

(1) *Dryness of the wood.*—Moist wood ignites with more difficulty and gives out less heat than dry wood, because much of the heat produced is absorbed in converting the water into vapour.

(2) *Anatomical structure.*—Porous wood ignites more readily and burns more rapidly than wood of dense structure, owing to the free admission of oxygen in porous woods. A steady heat is given out for a longer period by woods of dense structure than by porous woods.

(3) *Soundness.*—Unsound wood gives out less heat than sound wood, as loss of carbon and hydrogen is occasioned by the disintegration of the tissues. Decayed wood takes fire readily and burns slowly and without flame.

(4) *Presence of resins, oils, etc.*—The presence of resin, inflammable oil, and other similar substances increases the combustibility and heating power of wood: thus the small branches of many conifers burn readily when freshly cut and covered with needles. The resinous wood of the stumps of deodar and other conifers is used as torchwood on account of its inflammable nature; in the Khasia Hills and the Shan States the wood of *Pinus Khasya*, naturally very resinous, is artificially made more so for kindling purposes by cutting a hole in the lower part of the stem removing the bark and a little wood just above it; the wood above the hole, which gets saturated with resin, is then cut out and used for kindling. *Pinus excelsa* is treated similarly in some parts of the Himalayas.

(5) *Size of the pieces of wood.*—The smaller the pieces of wood used the quicker the combustion and the greater the heat given out in a short space of time, owing to the fact that oxygen can

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obtain ready access to the burning pieces of wood. If the fragments of wood are too small, however, combustion is retarded : thus sawdust burns with difficulty, merely smouldering and giving out little heat.

2. *Methods of determining the Heating Power of Woods.*

Various methods have been employed to determine the heating (or calorific) power of woods, but the figures obtained thereby are apt to be misleading, since a wood with a high calorific power is not necessarily a good fuel. The calorific power of fuel may be measured by the quantity of heat generated by the combustion of a unit weight of the fuel in oxygen, and is expressed either in calories or in British Thermal Units (B. T. U.). A calorie is the quantity of heat absorbed by one gram or kilogram of water when its temperature is raised 1° C, while a B. T. U. is the quantity absorbed by one pound of water when its temperature is raised 1° Fahr. The results of tests made in 1910-11 by Puran Singh with a number of Indian woods are given below.

Another common method of finding the calorific power of wood is to find the quantity of water at 0° C. which is evaporated by a unit weight of the wood at a given temperature and pressure ; the water, instead of being at 0° C. may be at boiling point when the experiment starts, the quantity of water evaporated by a unit weight of the wood being then determined. The results of tests made by this method in 1894-96 by Dr. Leather are given below. For the accurate comparison of the calorific powers of different woods, the samples should first be artificially dried till they have parted with all their moisture.

Some of Puran Singh's results, referred to above, are given in the following table, the woods being arranged in order of calorific power and the results expressed in B. T. U. :—

Species.	Calorific power (for completely dried woods) — B. T. U.
1 Pinus longifolia	9,144
2 „ excelsa	8,957
3 Shorea robusta	8,881

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	Species.	Calorific power (for completely dried woods) —B. T. U.
4	Terminalia tomentosa	8,862
5	Xylia dolabriformis	8,829
6	Bridelia retusa	8,829
7	Holoptelia integrifolia	8,788
8	Terminalia belerica	8,787
9	Pterocarpus macrocarpus	8,734
10	Acacia arabica	8,665
11	Carallia integerrima	8,579
12	Tectona grandis (Plantation grown)	8,568
13	Chloroxylon Swietenia	8,566
14	Tectona grandis (Naturally grown)	8,556
15	Albizzia procera	8,373
16	Ougeinia dalbergioides	8,368
17	Berrya Ammonilla	8,366
18	Dalbergia Sissoo	8,312
19	Casuarina equisetifolia	8,239
20	Cedrela Toona	8,239
21	Cedrus Deodara	8,239
22	Homalium tomentosum	8,239
23	Lagerstrœmia tomentosa	8,239
24	Picea Morinda	8,239
25	Acacia Catechu	8,219
26	Abies Pindrow	8,139
27	Kydia calycina	8,139
28	Bombax malabaricum	8,130
29	Gmelina arborea	8,075
30	Quercus dilatata	8,073
31	Garuga pinnata	7,950
32	Odina Wodier	7,909
33	Quercus incana	7,908
34	Oroxylum indicum	7,889
35	Lagerstrœmia parviflora	7,882
36	Boswellia serrata	7,765
37	Quercus semecarpifolia	7,585
38	Anogeissus latifolia	7,481
39	Calophyllum spectabile	7,389
40	Mallotus philippinensis	7,344
41	Pterocarpus Marsupium	7,324
42	Buchanania latifolia	7,322
43	Spondias mangifera	7,251
44	Sterculia villosa	7,251
45	Cassia Fistula	7,209
46	Adina cordifolia	6,939

Dr. Leather's results alluded to above are contained in the following table :—

Species.	Evaporative power (number of lbs. of water at 212° F. evaporated by 1 lb. of wood).
Acacia arabica (3 samples) . .	6·02—8·88
,, Catechu (13 ,,) . .	7·86—9·09
Albizzia amara	8·88
Anogeissus latifolia (3 samples) . .	7·65—9·01
Bamboos (3 ,,) . .	7·65—8·68
Boswellia serrata	8·27
Cleistanthus Collinus	7·86
Dillenia pentagyna (3 samples) . .	8·18—9·29
Diospyros Melanoxylon . . .	7·45
Dipterocarpus tuberculatus (4 samples) .	8·47—8·68
Eucalyptus Globulus	8·47
Eugenia Jambolana (6 samples) . .	8·16—8·79
Lagerstrœmia parviflora (3 samples) .	8·06—8·88
Phyllanthus Emblica	8·27

To compare these figures with B. T. U. they should be multiplied by 965·7.

3. *Value of Woods as Fuel.*

The value of a wood as fuel does not always depend on its calorific power, there being many other properties to take into consideration. Thus, although the calorific power of *Pinus longifolia* is exceptionally high, it is not a good fuel for ordinary purposes owing to the manner in which it crackles and throws out sparks; the wood of *Diospyros tomentosa* has a similar habit of throwing out sparks while burning. The woods of *Tamarix articulata* and *Kydia calycina* give an offensive smell when burning; that of *Rhododendron cinnabarinum* emits a smoke which causes irritation to the face and eyes. The wood of *Rhododendron arboreum* is apt to smoulder instead of burning with a flame, while that of *Boswellia serrata* burns readily in small pieces, but slowly and with much smoke in large billets. Teak-wood is not a suitable fuel for cooking purposes owing to its smokiness, though for heating purposes it is considered a good fuel.

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Although it is not always easy to find a reason for differences in the quality of woods as fuel, persons who are in the habit of burning wood, whether for domestic or for industrial purposes, can soon determine which woods are suitable and which are unsuitable for their requirements. Among woods which are considered bad as fuel may be mentioned *Michelia excelsa, Garuga pinnata, Dalbergia cultrata, D. paniculata, Pieris ovalifolia, Salvadora* spp., *Odina Wodier, Ficus* spp., *Mangifera indica, Bassia longifolia, Ailanthus excelsa, Buchanania latifolia, Bauhinia racemosa, Dolichandrone falcata,* as well as those above mentioned. Local custom sometimes regards fuel woods from different points of view: thus *Schleichera trijuga* is considered a good fuel in some parts, but in others it is not. *Acacia arabica,* too, although a good fuel, is sometimes objected to for locomotives on the ground (which may or may not be correct) that it injures the boilers in burning. The same objection is raised to *Morus indica.*

Fuel woods require different properties according to the uses to which they are put: for warming a room a steady continuous heat is desirable, whereas for bakers' ovens and brick-kilns an intense heat is required for a short time. Certain fragrant woods are burnt as incense, for example *Cupressus torulosa, Juniperus recurva, Taxus baccata* and *Santalum album.*

SECTION XII.—COLOUR, GRAIN, AND OTHER PROPERTIES.

The value of a wood for furniture, panelling, carving, turning, etc., depends largely on its colour, grain and texture; these and other properties, such as scent, may therefore be of considerable importance in affecting the demand for and the market price of various woods. We may conveniently deal with these properties separately under the heads of (1) Colour, (2) Grain and Texture, (3) Odour and other properties.

1. *Colour.*

There is an immense variety in the colours of the various Indian woods, but by far the majority are some shade of red, yellow, brown, or grey, while many are whitish

The sapwood is usually pale in colour and of little interest; it is the heartwood which generally supplies the woods sought after for their handsome colouring. Most woods darken with age, so that a wood which may be yellowish or pale brown when freshly felled often turns a rich brown on exposure to the air for a time; this is the case with teak, *Artocarpus Chaplasha* and *Lakoocha* and many other woods.

The Andaman *padauk* (*Pterocarpus dalbergioides*) owes its value as a decorative wood to its rich red colour; this colour, however, fades on exposure to the air unless the wood be treated by French polishing or some other process which will protect the surface. This loss of colour is noticeable in other woods besides *padauk*. Like certain other red woods, Andaman *padauk* varies greatly in the richness of its colour, even when freshly cut, the so-called "off-coloured" logs being far inferior in value to "prime-coloured" logs.

Some woods, instead of being uniform in colour, are streaked or mottled with darker or lighter markings: some of the most striking woods in this respect are to be found among the variegated ebonies, for example the woods known as the "Marble-wood" of the Andamans (*Diospyros Kurzii*) and the "Calamandar-wood" of Ceylon (*D. quæsita*), in which bands or streaks of black are intermingled with a groundwork of greyish colour. Other, though less striking, examples are the following:—

Species.	Colour of groundwork.	Colour of streaks.
Rhus Cotinus	Dark yellow	Brown.
Pistacia integerrima	Yellowish brown	Yellow and dark brown.
Mangifera indica (old trees)	Dark brown	
Dalbergia Sissoo	Brown	Black.
„ cultrata	Black	Dark brown.
„ Oliveri	Red	Dark purple.
„ latifolia	Dark purple	Dark red.
Pterocarpus Marsupium	Yellowish brown	Black.
Hardwickia binata	Dark purple or purplish-black	Brown. Black.
Albizzia Lebbek	Dark brown	Darker brown or light brown.
Terminalia tomentosa	Ditto	Darker brown.
Juglans regia	Greyish brown	Ditto.

As the colour often varies much in different specimens of one and the same species, it is not possible to classify woods strictly according to colour: in the following list will be found a few examples of the commoner Indian woods arranged as nearly as possible according to their usual colours (heartwood being understood if it exists):—

(*i*) White, yellowish-white, or greyish-white.—*Holarrhena antidysenterica*, *Bombax malabaricum*, *Sterculia alata*, *Erythrina* spp., *Wrightia tinctoria*, *Murraya exotica*, *Ægle Marmelos*, *Gardenia* spp., *Buxus sempervirens*, *Spondias mangifera*, *Gmelina arborea*.

(*ii*) Pale pink.—*Æsculus indica*, *Woodfordia floribunda*, *Rhododendron arboreum* (sometimes reddish-brown), *Betula utilis*.

(*iii*) Yellow (often turning brown).—*Berberis* spp., *Chloroxylon Swietenia*, *Sarcocephalus cordatus*, *Adina cordifolia*, *Morus* spp., *Artocarpus integrifolia*, *A. Chaplasha*, *A. Lakoocha*, *Cæsalpinia Sappan* (orange-yellow).

(*iv*) Grey.—*Kydia calycina*, *Mangifera indica* (young wood), *Duabanga sonneratioides*, *Diospyros montana*, *Stereospermum chelonoides*, *Ficus bengalensis*.

(*v*) Red of various shades, including reddish-grey.—*Dillenia indica*, *Mesua ferrea* (dark red), *Schima Wallichii*, *Heritiera minor* (dark red), *Melia indica*, *Cedrela Toona*, *Pterocarpus dalbergioides*, *P. santalinus* (dark red), *P. macrocarpus* (bright yellowish red to dark brick red), *Acacia Catechu*, *Careya arborea* (dull red), *Lagerstrœmia Flos-Reginæ*, *Dipterocarpus alatus* (greyish-red), *Dillenia pentagyna* (greyish-red), *Eugenia Jambolana* (greyish-red), *Pinus excelsa* (pale red).

(*vi*) Yellowish-brown or olive-brown.—*Chickrassia tabularis*, *Pterocarpus Marsupium*, *Tectona grandis* (turns dark brown), *Santalum album*, *Cedrus Deodara*, *Michelia excelsa*, *M. Champaca*.

(*vii*) Reddish-brown.—*Dipterocarpus tuberculatus*, *Garuga pinnata*, *Soymida febrifuga* (dark), *Schleichera trijuga* (light), *Ougeinia dalberg-*

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ioides, *Xylia dolabriformis*, *Acacia arabica* (pink when fresh cut), *Bassia latifolia*, *Quercus incana*.

(*viii*) Brown or greyish-brown.—*Shorea robusta*, *S. obtusa*, *Pentacme suavis*, *Dalbergia Sissoo*, *Albizzia Lebbek*, *Terminalia tomentosa*, *Cupressus torulosa*, *Lagerstrœmia parviflora*, *Juglans regia*.

(*ix*) Purplish.—*Dalbergia latifolia* (dark), *D. cultrata* (very dark), *Hardwickia binata* (dark), *Prosopis spicigera* (purplish-brown), *Terminalia Chebula*, *Anogeissus latifolia* (purplish-brown).

(*x*) Black.—*Diospyros Ebenum*, *D. tomentosa*, *D. Melanoxylon*, *Borassus flabellifer* (outer hard wood).

2. *Grain and Texture.*

As has already been seen, the grain and texture of a wood influence its hardness, weight, strength, fissibility, and other properties; here, however, we are concerned rather with the ornamental effects of grain and texture and with their effect on the working qualities of woods. Certain woods have such a cross-grained structure that it is difficult to get a plane sharp enough to plane them smooth, for example *Shorea robusta*, *Soymida febrifuga*, *Chickrassia tabularis*, *Hardwickia binata*, *Pterocarpus macrocarpus*, *Ougeinia dalbergioides*, and *Xylia dolabriformis*. A wavy grain often tends to make wood ornamental when cut longitudinally, by exposing alternate layers of fibres running in different directions on the cut surface.

Exaggerated waviness of fibre, or the presence of numerous dormant buds, may greatly increase the value of a wood for ornamental purposes; thus the "burrs" of *Albizzia Lebbek* and *Juglans regia* are very valuable, fetching a much higher price than the plain wood; the burrs on *Terminalia tomentosa* also produce a handsome wood, not unlike walnut. The ornamental "bird's-eye" maple receives its markings from dormant buds, round which the fibres twist in various directions. The teak grown on the banks of the Godavari in open situations has a gnarled appearance, and produces a timber which, by reason of its beautiful wavy grain, commands an exceptionally high price for cabinet work.

The capacity of a wood for taking a good polish depends largely on its grain and texture, loose-textured soft or rough woods being inferior in this respect to more compact finer grained woods. Among common examples of rough woods may be mentioned *Dillenia pentagyna*, *Schima Wallichii*, *Mangifera indica*, and *Eugenia Jambolana*.

For ornamental purposes one of the most important requirements of a wood is a good silver-grain, which is exposed on a radial section, the medullary rays being cut lengthwise. Some woods possess no conspicuous silver-grain, but others, particularly those with large or medium-sized medullary rays, show it to great advantage : handsome woods, however, are frequently spoiled through faulty conversion, for it is often forgotten that to display the silver-grain the wood must be cut on a radial section or as nearly so as possible. Among woods conspicuous for their handsome silver-grain are *Carallia integerrima*, *Rhizophora mucronata*, *Prunus Puddum*, *Cordia vestita*, *Ilex* spp., *Acer* spp., *Quercus* spp., and several of the *Meliaceæ*, particularly *Soymida febrifuga*, *Chickrassia tabularis*, and *Chloroxylon Swietenia*.

3. *Odour and other Properties.*

Odour may affect the value of a wood favourably or adversely, according to its fragrance or disagreeableness. The most important of the fragrant woods of India is *Santalum album*, the Sandalwood of Southern India. Another fragrant wood is the Burmese "Kalamet," *Mansonia Gagei*. *Aquilaria Agallocha*, a tree of North-East India and Tenasserim, gives the fragrant "Eaglewood" of commerce, found as masses of harder and darker-coloured wood in the interior of old trees. Among other woods possessing a certain fragrance may be mentioned *Cordia fragrantissima*, *Alangium Lamarckii*, *Premna integrifolia*, *Melia indica*, *Cupressus torulosa*, *Cedrus Deodara*, *Pterocarpus macrocarpus*, *Olea dioica* and *Cinnamomum* spp., including the well-known camphor-wood of Japan (*Cinnamomum Camphora*).

Many woods have a more or less disagreeable odour, common examples being *Sterculia urens*, *Cedrela serrata*, and *Grewia oppositifolia*, particularly when fresh cut. Some woods have other noxious properties; for example that of *Semecarpus Anacardium* contains an acrid juice, and timber cutters dislike cutting it owing to the irritation and swelling which the juice causes; similarly *Holigarna Helferi*, also belonging to the *Anacardiaceæ,* has a black acrid juice which raises blisters.

SECTION XIII—FREEDOM OR OTHERWISE FROM DEFECTS OR UNSOUNDNESS.

Under defects and unsoundness in wood are included all abnormal conditions of the wood which permanently reduce its utility. Unsoundness, being due to one particular cause, namely, the attacks of fungi, will be considered separately; under defects may be included various abnormalities which will be dealt with first.

1. *Defects.*

Defects may be broadly divided into four classes, (1) *Defects due to rupture of the tissues,* (2) *Defects due to manner of growth,* (3) *Defects due to the presence of healed wounds,* (4) *Defects due to the attacks of insects or parasitic plants.*

(1) DEFECTS DUE TO RUPTURE OF THE TISSUES.

Such defects, which are technically known as *shakes,* are caused by the separation of the fibres along one or more lines, which may be comparatively short or may extend throughout the length of the tree. Shakes are of three kinds, (*a*) *Heart-shake,* (*b*) *Radial-shake,* (*c*) *Cup-shake.*

(*a*) *Heart-shake.*—Heart-shake consists of a crack starting from the pith and extending outwards more or less radially. When there is only one crack, which may extend right across the pith, it is termed *simple heart-shake* (*vide* Plate I, fig. 1), but when there are several cracks radiating out from the centre it is termed *compound heart-shake* or *star-shake* (*vide* Plate I, fig. 2). Heart-shakes occur chiefly near the base of a tree, but may extend right up. They are caused usually by shrinkage of the inner tissues as the wood in the centre dries; hence old trees, whose interior tissues have dried to some extent, and trees growing on unfavourable soils, are most liable to them. Heart-shakes in trees may also be caused by shock, whether by another tree in falling, or by the action of the wind, or when the tree itself is felled. After a heart-shaken tree is felled the heart-shake tends to spread further

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during the drying of the timber: to prevent this as much as possible the wood should be slowly seasoned. A heart-shake consisting of only one crack may not reduce the value of a log much for sawing purposes, particularly if the crack be a straight one, but if there are many cracks radiating the log is of little use as timber.

(*b*) *Radial-shake* (*vide* Plate I, fig. 3).—Radial-shakes are cracks commencing from the outside of the stem and extending radially inwards: they are caused by the contraction of the outer tissues, this contraction being most commonly due to the action of frost, in which case the defect is known as *frost-crack*. Radial-shakes may also be caused by sudden and excessive heat, such as a hot sun after a cold night, blasts of hot wind, or forest fires; these cracks may be aggravated by strong winds, causing the tree to bend and the cracks to extend further up the stem. Radial-shakes may close up shortly after being formed, but in the case of annual severe frosts or fires the crack may be kept open year after year, and a ridge is formed up the side of the stem owing to the more rapid growth of the tissues along the crack, where the pressure of the cortex is removed: in the case of frost-cracks these ridges are called frost-ribs. Trees which split easily are most subject to radial-shakes.

(*c*) *Cup-shake.*—A cup-shake is formed when the crack follows the direction of the annual rings (*vide* Plate I, fig. 4); it may extend for a distance varying from a few inches to the whole way round, in which case it is termed *ring-shake.* Cup-shake may be caused in various ways, for example by the shrinkage of the central tissues owing to the loss of moisture, by the action of frost, fire, or other forms of injury to the cambium, or by shock produced when the tree sways during a high wind, or when another tree falls against it, or when the tree itself falls. Cup-shake has also been known to follow a complete defoliation by caterpillars, giving a severe check to the nutrition of the tree, whereby the new wood fails to adhere to that of the previous year; it has also been observed to have been caused by fungus attacks where the mycelium spreads up the cambium. The degree in which cup-shake renders a piece of timber unserviceable depends on the extent of the defect and on the purpose for which the wood is required. Sometimes a combination of two or all three kinds of shakes occurs in one piece of timber, rendering it useless except as fuel (*vide* Plate I, fig. 5).

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DEFECTS IN TIMBER.

PLATE I.

1. Transverse section of stem of Santalum album, showing heart-shake, with tendency to star-shake. (Reduced $\frac{1}{10}$).
2. Transverse section of stem of Cedrus Deodara, showing more extensive star-shake. (Reduced $\frac{1}{18}$).
3. Transverse section of stem of Phyllanthus Emblica, showing radial-shake due to cracking by intense heat in the Central Provinces. (Reduced $\frac{2}{5}$).
4. Transverse section of stem of Cupressus torulosa, showing cup-shake. (Reduced $\frac{1}{5}$).
5. Transverse section of stem of Cedrus Deodara, showing combination of heart-shake and cup-shake. (Reduced $\frac{1}{15}$).
6. Transverse section of stem of Picea Morinda at a point where a whorl of branches is produced, showing formation of knots in the wood. (Reduced $\frac{1}{12}$).

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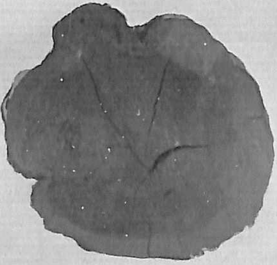
PLATE 1.

1



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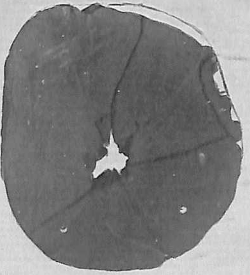

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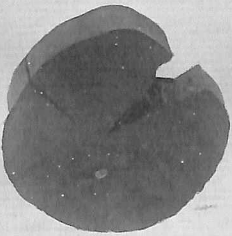

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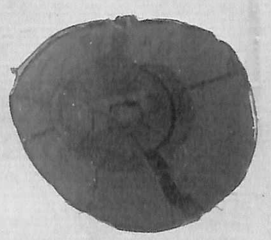

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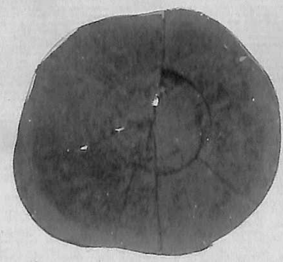

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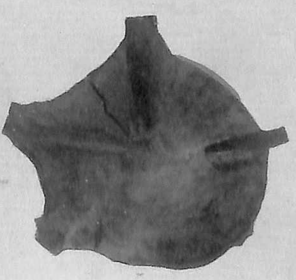

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(2) DEFECTS DUE TO MANNER OF GROWTH.

(*a*) *Twisted fibre.*—In this defect the grain of the wood, instead of running straight up the tree, twists spirally round the axis. The twist may occur from right to left or from left to right, the direction being constant in some species, but apparently not so in all. Certain species are more liable to twisted fibre than others, for example *Hardwickia binata*, *Populus euphratica*, *Boswellia serrata*, *Casuarina equisetifolia*, and *Pinus longifolia* are often affected. The cause of this twisted growth is not accurately known: it is, however, more prevalent in some places than in others and is possibly due, in some cases at least, to shallowness and poverty of soil. Trees with twisted fibres can often be recognised by the corresponding twist in the bark, which is visible externally. Wood with twisted fibre is not suitable for sawing into planks, as the wood is liable to warp, and it is also unsuitable for any purpose where straight split-wood is required; it can, however, be used for large beams.

(*b*) *Knottiness.*—Knots are portions of branches which have become enclosed in the wood (*vide* Plate I, fig. 6). In broad-leaved species these knots do not differ in texture from the wood of the stem to such an extent as is the case in conifers, where the knots are often very hard and tend to become loose and fall out of sawn boards. The presence of knots in large timber is not such a great disadvantage as it is in the case of sawn planks and scantlings, where their presence increases the difficulty of sawing and planing, and weakens the boards, especially when the knot runs across the breadth of the board. Knots are objected to in railway sleepers, particularly at the points where the spikes holding the rails are driven in. The presence of knots in timber can be reduced to a minimum by growing dense-canopied woods in which the trees have no opportunity of sending out large side branches.

(*c*) *Wavy wood and burrs* (*vide* Plate II, fig. 1.)—These are more characteristic of some species than of others, and as already explained in Section XII, they may greatly increase the value of a wood for ornamental purposes; where strength or fissibility are required, however, they can be regarded only as defects.

(*d*) *Interior bast tissue.*—The stems of certain species have a peculiar structure in that the tissues of the wood are separated at intervals by tissues of interior bast (*vide* Plate II, fig. 2.): this is seen in *Bauhinia Vahlii*, *Millettia auriculata*, *Dalbergia paniculata*, *Cocculus laurifolius*, many *Convolvulaceæ*, and certain *Capparideæ*, such as *Niebuhria linearis*, *Mœrua arenaria*, and *Cadaba trifoliata*. Such a structure naturally renders wood useless as timber. Bark and bast may sometimes be included within the stem of a tree by the growing together of two branches (*vide* Plate II, fig. 3), or when the trunk is strongly fluted, long strands of bast and bark being grown over at the fluted parts and remaining within the wood (*vide* Plate II, fig. 4). Such a defect, which sometimes occurs in teak, reduces the size of the squares and planks which can be cut out of the logs.

(*e*) *Contortion produced by the encircling of climbers.*—The effects produced by climbers on the shape and development of trees are different according to the manner in which the climbers grow; some, like *Rosa moschata* and *Acacia pennata*, cling on by means of their prickles, while others twine round the stems of trees. As far as the shape of the bole goes the latter class is the more troublesome, in that the large twiners so common in tropical forests may so contort the stems of otherwise sound and valuable trees as to render them useless for timber (*vide* Plate II, fig. 5). Systematic cutting of climbers in the forests is the only preventive of this serious defect in the timber of trees infested by them.

(3) DEFECTS DUE TO PRESENCE OF HEALED WOUNDS.

(*a*) *Covered surfaces of pruned branches.*—However carefully a branch may be pruned, the new wood which grows over the wound never joins completely with the pruned surface, and even if the surface be tarred it is difficult to prevent the ingress of fungi causing rot in the wood. Even the most careful pruning therefore results in a defect in the wood which considerably reduces its value (*vide* Plate II, fig. 6).

(*b*) *Occluded broken branches.*—Where a branch is broken off a hollow usually forms, into which water settles; this induces rot, which may spread right into the heart of the tree and extend up and down the stem for some distance on either side of the wound (*vide* Plate II, fig. 7). The wound itself takes a longer time to heal up than in the case of a pruned branch, so that the damage done by fungus attacks during the process of healing is more extensive owing to its duration.

DEFECTS IN TIMBER—(CONTINUED).

PLATE II.

1. Longitudinal section of stem of *Anogeissus latifolia*, showing outgrowth known as a "burr." (Reduced $\frac{1}{26}$).
2. Transverse section of stem of *Dalbergia paniculata*, showing natural interior bast tissue. (Reduced $\frac{1}{6}$).
3. Transverse section of stem of *Ougeinia dalbergioides*, showing occluded bast tissue owing to growing together of two branches. (Reduced $\frac{1}{6}$).
4. Transverse section of stem of *Acacia Intsia*, showing formation of interior bast tissue owing to fluting of the stem. (Reduced $\frac{1}{8}$).
5. Longitudinal section of stem of *Shorea robusta*, showing contorted growth due to constriction by climbers. (Reduced $\frac{1}{14}$).
6. Longitudinal section of stem of *Cedrela Toona*, showing occluded pruned branch. (Reduced $\frac{1}{4}$).
7. Longitudinal section of stem of *Quercus incana*, showing occlusion of broken branch with attendant decay. (Reduced $\frac{1}{3}$).
8. Transverse section of stem of *Shorea robusta*, showing rindgall. (Reduced $\frac{1}{12}$).

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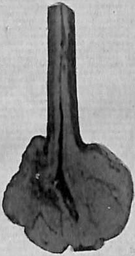
PLATE 2.

1



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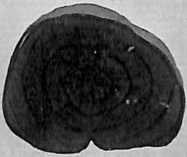

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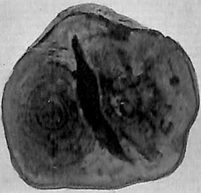

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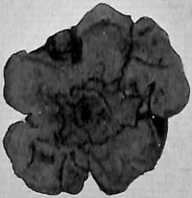

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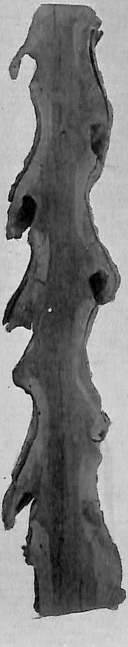

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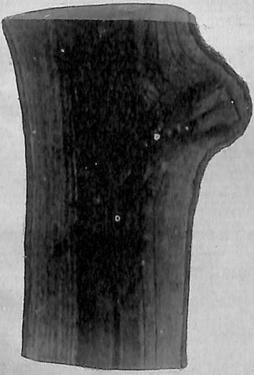

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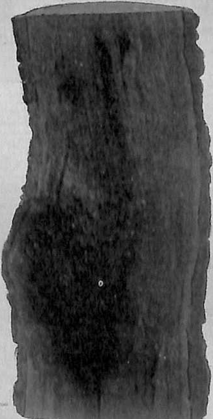

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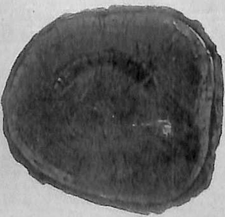

Photo.-Mechl. Dept., Thomason College, Roorkee.

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(*c*) *Rindgalls.*—These are defects in timber due to the inclusion within the wood of old healed wounds which may be caused by a variety of circumstances, such as passing carts, falling trees, barking by deer, bears, and other animals, fire, etc. During the process of healing rot is very liable to enter the wound and spread inwards, while the new wood over the wound does not join completely with the old wood, thus producing a defect, which may be discovered only when the timber is sawn up (*vide* Plate II, fig. 8).

(4) Defects due to Attacks of Insects or Parasitic Plants.

(*a*) *Insects.*—The insects which directly affect the commercial value of timber are the wood-borers, whose attacks are at times so destructive as to render wood quite useless as timber. We may divide these insects into two classes according to their modes of attack :—

(*i*) *Insects which bore into living trees to lay their eggs or pupate.*—Against these successful preventive measures are most difficult. Some of the most destructive insects of this class known at present are the larva of the moth *Duomitus ceramicus*, popularly but erroneously called the "bee-hole borer" of teak (which bores large tunnels in teak trees in Burma and may so reduce the value of the wood as to make it useless except as fuel), *Stromatium* sp., a longicorn beetle which bores into the heartwood of Sandalwood trees, and *Apate jesuita*, a bostrichid beetle which bores into *Casuarina* stems.

(*ii*) *Insects which bore into dying or dead trees, or into newly-felled or partly-dried timber.*—These are dealt with differently according to whether they lay their eggs in the bark or bore into the wood to lay them ; in the former case the wood should be barked as soon as felled, while in the latter case all dying or dead trees should be felled, and all newly-felled timber of any kind should be removed as soon as possible, a further safeguard being to place the timber in water at once. There are many

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important boring beetles of this class, chiefly bostrichids, scolytids, and cerambycids. Probably the most destructive *sál* borers are *Æolesthes holosericea* and *Hoplocerambyx spinicornis,* which bore tunnels from ½″ to ¾″ in diameter right into the heart-wood in order to pupate. The eggs are laid in the bark, chiefly of newly-felled wood; hence the necessity for barking the wood as soon as the trees are felled.

(*b*) *Parasitic plants.*—Fungus attacks are dealt with below, under *unsoundness;* other parasitic plants are not usually of much consequence except where the wood of the branches and upper parts of the stem is concerned. These plants belong chiefly to the order *Loranthaceæ*, the best known belonging to the genera *Loranthus* and *Viscum;* they do damage by sending in *haustoria* which produce holes in the wood of their host, rendering it useless as timber and reducing its value as fuel.

2. *Unsoundness.*

(1) GENERAL ACCOUNT.

The decay of timber in use has already been dealt with in Section X. We are here concerned with decay or unsoundness which enters the wood of standing trees and reduces its value. Slow decay may be caused by the oxidation and consequent decomposition of the tissues, particularly in old trees. The most destructive form of decay, however, is caused by the attacks of fungi, whose hyphæ penetrate into the wood and break down the tissues, causing rottenness, which is popularly termed *red-rot* or *white-rot* according to its colour. These fungi may obtain access through wounds in the bark, through the roots, or at the place where a branch has broken off, the water which settles there greatly facilitating the spread of the fungoid attack. Decay spreads rapidly into the tree, and may sometimes render the interior of the whole stem rotten, though the attack may often be merely local and only affect a small portion of the stem. When the disease appears on the outside of the tree the affected portion is known as *canker.* Among root-parasites, that is, fungi which enter the stem through the roots, the most destructive hitherto detected in

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India is *Fomes annosus*, better known as *Trametes radiciperda*, which kills young deodar trees in the Himalayas and affects the wood of the lower part of the stem. Among those which attack the stem may be mentioned *Trametes Pini*, which causes red-rot in *Pinus excelsa*, *Polystrictus egregius*, which attacks *Dalbergia Sissoo*, *Fomes* (*Polyporus*) *fomentarius*, found on *Quercus incana* and *Betula alnoides*, and *Fomes fulvus* and *F. Pappianus* which do much damage to *Xylia dolabriformis* and *Acacia arabica* respectively.

(2) DETECTION OF UNSOUNDNESS.

(*a*) *In standing trees.*—Unsoundness may often be detected in standing trees by careful examination, though it is more difficult than in the case of felled timber. The tree should be examined for stag-headedness, the presence of broken dead branches, holes in the stem, swellings produced by the occlusion of wounds, signs of canker, blistering, or an abnormal flow of resin, gum, etc. ; these may all be indications of decay. Finally, the stem should be struck with the back of an axe or similar implement, when a hollow sound will indicate a cavity, a dull soft sound the presence of decay, while a clear ringing sound, though not always a proof of complete soundness, will at any rate show that there is a considerable thickness of sound wood on the outside.

(*b*) *In felled timber.*—The detection of unsoundness in felled timber is easier than in the case of standing trees. The ends of the logs should be examined for hollows, decay, and suspicious colouring or odour. If a hollow be found its length may be approximately determined by probing with a long pole or bamboo. Abnormal swellings on the side of the log should be cut open or bored into with an auger, the fragments extracted being examined for decay, which may be detected by the appearance, texture, colour, and odour of the chips. The log should also be hammered at different points in order to test the presence of hollows or decay. The examination of timber is easier when the logs are properly arranged on dry land than when floating in a river, lying in mud, or heaped up indiscriminately ; hence the importance of arranging timber exposed for sale in such a manner that intending purchasers may have no difficulty in examining it.

CHAPTER II.

Industrial Uses of Wood.

There are few substances more widely used than wood, and although iron has superseded wood for many purposes, yet statistics show that the world's consumption of wood is steadily increasing; a study of its various principal uses is therefore necessary to any one who is concerned in its production. Wood may be broadly classified, according to the uses to which it is put, into *A.—Timber* and *B.—Firewood.*

A.—TIMBER.

SECTION I.—CLASSIFICATION OF TIMBER.

The classification of timber varies greatly according to local custom, and no system can be said to be universally applicable. Omitting special classes of wood, such as paving-blocks, shingles, etc., we may take the following as a general classification of timber used for ordinary purposes:—

(1) *Round timber*, that is, timber obtained by felling trees, removing the branches, and cutting the boles into pieces of convenient length, these pieces being variously classed according to dimensions as *mast-pieces, logs, butts* and *top-pieces* (short pieces cut off the thick and thin ends of logs respectively), *spars* (long poles), *poles, posts,* and *billets,* the last named however being commonly obtained from branches, except in the case of small trees. The sapwood is often removed, or the timber may be otherwise roughly shaped to polygonal section, in which case it is commonly termed *rough timber.* Timber in the round is used for masts, piles, telegraph poles, and many other purposes.

(2) *Squared timber.*—Such timber is roughly squared with an axe or saw, squared logs being known

as *balks*, which are of two kinds, (*a*) *Squares*, that is, completely squared logs, with rectangular corners, and (*b*) *Waney balks*, where the rounded surface of the log is left at each corner, these natural surfaces being called the *wanes*, and the trimmed sides being called the *panes*. When balks or round logs are split in two down the centre, each piece is termed a *half-balk*.

(3) *Sawn timber.*—Such timber cannot be classed according to any hard and fast rule, but the following classification according to breadth and thickness may be taken as being fairly general:—

Beams—9″ × 9″ to 18″ × 18″ (for large beams in houses, bridges, etc).

Scantlings—4″ × 5″ to 9″ × 9″ (for supporting floors and roofs, etc.).

Planks—10″ × 2″ to 18″ × 6″ (for wagons, bridges, and other purposes where thick planking is required).

Boards and *deals*—(the latter being boards made of coniferous wood); 6″ × ½″ to 12″ × 1¾″ (for floors, door-panels, boxes, etc.).

Battens—4″ × ¾″ to 7″ × 3″ (for door and window frames, etc.).

Laths—2″ × ½″ to 4″ × 1″ (for lattice-work, supporting shingles on roofs, etc.).

SECTION II.—TIMBER USED IN SUPERSTRUCTURES.

The term *superstructure* includes all parts of buildings, bridges, and similar structures which are not actually in contact with the ground or with water on or in the ground.

1. *Superstructures of Buildings.*

The quantity of timber used in house-building depends largely on the available supply of that material; thus in richly wooded countries houses are frequently built entirely of wood, while in sparsely-wooded countries the amount of wood used in construction is reduced to a minimum, and consists only of that required for doors, windows, beams and rafters, and a few other purposes, the remainder of the building consisting of mud, stone, brick, or other material according to the class of building and the available supply of building materials. For the superstructures of permanent buildings of the better class the timber should be strong and durable, strength being required especially in joists, beams, and rafters, and durability being particularly necessary where the timber is in contact with masonry. Lightness is a great *desideratum*, especially for timber in the roof, provided strength and durability are not sacrificed in the endeavour to obtain a light wood. For flooring and wall-planking the timber should not be liable to warp or shrink, and should therefore be well seasoned, while timber for such interior work as panelling, ceilings, etc., should be ornamental. Timber for interior work is not so severely tried as that exposed to alternations of rain and sun, such as wood used for external plank walls, shingles, etc., which are liable to warp and split; wood so exposed may be preserved by being periodically smeared with crude earth-oil.

2. *Superstructures of Bridges.*

Timber for bridges being particularly exposed to the influence of the weather, and being subjected to much strain by the application of heavy weights, great strength and durability, as well as elasticity, are necessary, while if the road-surface is paved with wood this should be tough and hard.

3. *Woods employed for Superstructures.*

The employment of a building timber largely depends, apart from its suitability, on its prevalence in a given locality, while local custom and prejudice are often strong factors in determining the extent to which a wood is employed. In India it may be said that three timbers stand out above all others as building timbers in their respective regions: these are deodar in the Himalayas and adjacent tracts, *sál* throughout a great part of Northern India and the north of the Peninsula, and teak in Burma and over the greater part of the Indian Peninsula. Deodar, however, is sometimes objected to for internal work owing to its strong odour. In addition to these three, the following list of timbers, though representing but a mere fraction of the building timbers of India, embraces every province, some of the woods being used only locally and others having a wide range:—

Abies Pindrow: interior planking (Himalayas).

Acacia arabica: beams, rafters, door-frames, etc.

A. Catechu: beams, rafters, door-frames, etc.

Adina cordifolia: beams, scantlings and planking.

Albizzia Lebbek: beams, scantlings and planking.

A. procera: beams, scantlings and planking.

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Anogeissus latifolia: poles and rafters.

A. pendula: used for poles and rafters in Ajmer-Merwara and Rajputana.

Artocarpus Chaplasha: beams, planking, door and window-frames, etc.

A. hirsuta: used for house-building in South India.

Berrya Ammonilla: used for beams and scantlings in Burma.

Bischofia javanica: bridges and houses, planking, etc.

Calophyllum Inophyllum: used for house-building in Madras.

Careya arborea: planking and general construction.

Cassia Fistula: beams and scantlings.

Casuarina equisetifolia: poles and rafters (Madras).

Cedrela Toona: door-panels and planking; sometimes used for beams and scantlings.

Cedrus Deodara: much used in bridge and house construction.

Chickrassia tabularis: beams, scantlings and planking (Chittagong).

Chloroxylon Swietenia: house and bridge construction.

Cinnamomum Cecidodaphne: planking (North-Eastern Himalayas).

Cocos nucifera: rafters and ridge-poles.

Dalbergia latifolia: door and window-frames, and scantlings.

D. Sissoo: beams, rafters, scantlings, door and window-frames, etc.

Dipterocarpus tuberculatus: much used in Burma for planking, scantlings, door and window-frames, etc.

D. turbinatus: beams, scantlings, planking, etc.

Duabanga sonneratioides: beams, scantlings and planking (Bengal and Assam).

Eugenia Jambolana: beams rafters and scantlings.

Fagræa fragrans: house and bridge-building (Burma).

Gmelina arborea: planking, panelling, door and window-frames.

Hardwickia binata: beams and rafters, and where great strength is required, as in bridges.

Heritiera minor: beams, planks, door and window frames, and general house and bridge construction (Bengal).

Hopea odorata: bridge and house construction, beams and scantlings; a durable timber (Burma).

H. parviflora: bridge and house-building; an important timber of South India.

H. Wightiana: bridge and house-building; an important timber of South India.

Juglans regia: beams, scantlings, planking, panelling, etc. (Himalayas).

Lagerstræmia Flos-Reginæ: planking, beams, rafters, etc.

L. lanceolata: planking, beams, rafters, etc. (Bombay and Madras).

Melia indica: scantlings and light beams, door and window frames.

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Mesua ferrea: house and bridge building; beams, scantlings, etc.; very strong and durable, but excessively hard and heavy.

Michelia excelsa: an important building timber in the N. E. Himalayas.

Pentacme suavis: beams, rafters, and scantlings; very durable (Burma).

Picea Morinda: interior planking (Himalayas).

Pinus excelsa: general house construction, beams, scantlings, planking, doors and windows (Himalayas).

P. Khasya: ditto. (Khasia Hills).

P. longifolia: ditto. (Himalayas).

Pterocarpus dalbergioides: planking, panelling, and ornamental work; used in the Andamans for bridge planking and general construction.

P. macrocarpus: beams and scantlings; suitable for bridge construction and wherever great strength and durability are required (Burma).

P. Marsupium: beams, scantlings, door and window frames, etc., one of the chief building timbers of the Central Provinces.

P. santalinus: door and window frames and ornamental work, such as carved verandah posts.

Quercus dilatata: beams, rafters, etc. (North West Himalayas).

Q. fenestrata: beams, rafters, etc. (North East Himalayas and Khasia Hills).

Q. lamellosa: ditto. (North East Himalayas).

Schima Wallichii: beams, rafters, planking, etc., for houses and bridges (North Bengal and Assam).

Shorea assamica: planking and bridge constructions (Assam).

S. obtusa: house and bridge construction, beams, rafters, scantlings, etc.; very durable and much used in Burma.

S. robusta: much used for house and bridge construction, beams, rafters, door and window frames, etc.

S. Talura: ditto. (Madras).

S. Tumbuggaia: ditto. (Madras).

Soymida febrifuga: beams, scantlings, doors and windows.

Tectona grandis: extensively used for the better class of house building work of all kinds and for bridge construction.

Terminalia belerica: scantlings and planking.

T Chebula: beams, scantlings, planking, door and window frames.

T. paniculata: beams, rafters, planking, etc. (Bombay and Madras).

T. tomentosa: beams, rafters, scantlings, and planking for houses and bridges.

Xylia dolabriformis: largely used for house and bridge construction in Burma and the Peninsula of India.

In addition to these may be mentioned bamboos, which are extensively used for roofing, walls, flooring, etc.

In some cases there is no accounting for local prejudices among the people against certain timbers for building pur-

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poses: such ideas are often mere superstitions, for example the prejudice against *Acacia Catechu* in some parts of the United Provinces, *Albizzia Lebbek* in parts of Madras, and *Terminalia belerica* in Mysore.

SECTION III.—TIMBER USED IN CONTACT WITH THE GROUND.

Under this head may be included timber employed for piles, house-posts, telegraph-poles, fence-posts, mine-props, paving-blocks, and railway sleepers.

1. *Piles.*

When bridges, large buildings, or other heavy structures have to be built on soft earth it is necessary first to prepare a solid foundation by driving in wooden piles to support the structure. Such timber is greatly exposed to the action of fungi unless it is completely covered with water, as in the case of bridge piles: for this reason it should possess great durability, while it should be tough in order to resist shearing and splitting when driven in by the heavy blows of the pile-driver. Piles should be made of round timber, in order to preserve their strength and lessen the work of driving them in; for this reason the best piles are obtained from straight clean boles.

The following are some of the chief woods used for piles:

Acacia Catechu.
Artocarpus Lakoocha.
Bassia longifolia.
Bischofia javanica.
Cassia Fistula.
Chloroxylon Swietenia.
Careya arborea.
Cedrus Deodara.
Fagræa fragrans.
Hardwickia binata.
Heritiera minor.
Hopea odorata.
H. parviflora.
H. Wightiana.
Lagerstrœmia Flos-Reginæ.
Mesua ferrea.
Mimusops Elengi.
M. hexandra.
M. littoralis.
Pentacme suavis.
Premna bengalensis.
Pterocarpus dalbergioides.
Shorea obtusa.
S. robusta.
Tectona grandis.
Terminalia tomentosa.
Xylia dolabriformis.

2. *House-Posts and Fence-Posts.*

Timber employed for these purposes is much subject to decay, especially near the surface of the ground, and it should therefore be as sound and durable as possible, sapwood being removed. Straightness is a necessary quality for house-posts, and as they have to bear considerable weight, strength is a further requisite. The species mentioned above as suitable for piles are also suitable for house-posts and fence-posts, while in addition may be mentioned the following :—

Acacia arabica.
Albizzia Lebbek.
A. procera.
Artocarpus Chaplasha.
A. hirsuta.
Bassia latifolia.
Berrya Ammonilla.
Borassus flabellifer.
Bridelia retusa.
Chickrassia tabularis.
Cleistanthus collinus.
Cocos nucifera.
Cupressus torulosa.
Dalbergia latifolia.
D. Sissoo.
Diospyros Melanoxylon.
D. tomentosa.
Eugenia Jambolana.
Garcinia speciosa.
Lagerstræmia lanceolata.
L. parviflora.
Melanorrhœa usitata.
Melia indica.
Ougeinia dalbergioides.
Phœnix sylvestris.
Pterocarpus macrocarpus.
P. Marsupium.
P. santalinus.
Shorea Talura.
S. Tumbuggaia.
Soymida febrifuga.

3. *Telegraph Poles.*

Few woods are now used for telegraph poles in India, except for temporary lines. The more durable woods suitable for piles and for house-posts could if necessary be employed for the purpose. In Burma the woods used are teak, *Xylia dolabriformis*, *Lagerstræmia Flos-Reginæ*, *Pentacme suavis* and *Shorea obtusa*. Only heartwood is used, and the poles are not treated in any way except that they are usually charred or coated with tar at the base. With the exception of teak, which is too expensive for general use, *Xylia* lasts better than the others.

On the North-West Frontier, deodar, birch (*Betula utilis*), white poplar (*Populus alba*) and pine have been employed, but of these deodar is the only wood which has

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been found to last well. The poles are usually charred or tarred at the base.

4. *Mine Props.*

Mining-timber is required for supporting the galleries of mines, and as it is employed in moist still air and often in contact with damp soil, it is much exposed to decay. For this reason durable timber should be employed, while it should also be sufficiently strong to support the sides and top of the gallery.

Mining-timber is usually employed in the round, in the form of poles and posts. Where mine-props are much in demand the most durable timber is often not available in quantity sufficient to supply the demand, in which case less suitable timbers have to be employed. Timbers which have been found most suitable in the Warora colliery, Central Provinces, are *Terminalia tomentosa* and *Diospyros Melanoxylon*, while those employed at the Mohpani colliery, Central Provinces, are *Terminalia tomentosa*, *Boswellia serrata*, *Odina Wodier*, and *Buchanania latifolia* : other timbers are also accepted if of the proper size, provided they are sufficiently durable. The principal sizes of props required are 6 to 12 feet in length and 4 to 6 inches in diameter ; logs of *Terminalia tomentosa* over 3 feet in girth and 15 to 20 feet in length are also employed. In the Kolar gold fields *Añogeissus latifolia*, *Hopea parviflora*, *Shorea Talura* and *Terminalia paniculata* are among the commonest timbers used. In the Dandhot colliery, Punjab, the timbers employed are *Cedrus Deodara*, *Pinus excelsa* and *P. longifolia*.

5. *Paving-blocks.*

Wooden blocks have for many years been employed for paving the surface of the streets of large towns, and this form of paving, which has been found most successful, is coming more and more into use. The blocks used vary as a rule from 6″ to 10″ in length, 3″ to 4″ in width, and 4″ to 6″ in depth : they are laid with the grain vertical on a firm foundation of concrete 5″ or 6″ thick, and cemented together by pitch poured between them in a molten state. Wooden street-paving forms a durable and comparatively noiseless road-surface, while the quantity of dust and mud produced is small compared with that produced on a macadamized road. It is essential that the concrete foundation should be perfectly firm and that the wooden blocks should be of uniform quality, otherwise the road-surface wears away unevenly, and hollows are formed. In London the woods most largely employed are creosoted pine and the Australian woods jarrah (*Eucalyptus marginata*) and karri (*E. diversicolor*). The main requisites are durability, resistance to wear and tear, and freedom from undue tendency to expand and contract, to absorb liquid, or to wear unevenly, that is, the texture of the wood should be even. Some of the streets of Rangoon were laid with blocks of teak and *pyinkado* (*Xylia dolabriformis*) in 1896 and subsequent years, and the blocks have been found to wear very well, the earliest pavement laid down being in good order 14 years later, and requiring little or no repair. Blocks of *Dipterocarpus tuberculatus* were tried for wood-paving in Rangoon some years ago, but were found unsuccessful; besides failing in durability, they absorbed much liquid, and soon gave off an offensive odour. Many of the more durable Indian woods might, if given a fair trial, be found to answer well for wood-paving.

6. *Railway Sleepers.*

(1) PROPERTIES REQUIRED.

Wood for railway sleepers should be durable, in order to withstand the attacks of insects and fungi and the climatic influences to which it is exposed: it should also be hard and tough enough to resist the cutting and crushing action of the rail or chair placed on it, and the strain to which it is subjected by the constant passing of heavy traffic over it. The wood should in addition be free from shakes and other defects, sound, free from sapwood, and not liable to warp and split. The sleepers themselves should be cut straight and of the correct dimensions, while they should be free from knots at the points where the spikes which hold the rail are driven into them; they should also possess the property of holding the spikes well after they have been driven in. Half-round sleepers have a very limited use in India, the great majority of railways insisting on having squared sleepers.

(2) DIMENSIONS OF SLEEPERS.

In India there are four different gauges of railway lines, 5 feet 6 inches (broad gauge), 3 feet 3⅜ inches (metre-gauge), 2 feet 6 inches and 2 feet 0 inch (narrow gauges). There is a standard size of sleeper for each gauge, but in practice the actual size varies slightly on different railways. The following table gives the dimensions of sleepers for each gauge and the number of sleepers required per mile of rail :—

Gauge.	Standard dimensions of sleepers.	Dimensions actually employed.	Standard number of sleepers per mile.	Actual number of sleepers used per mile.
5′-6″	9′ 6″×10″×5″	9′ 0″×9″×5″ to 10′ 0″×10″×5′	1,906	1,760 to 2,200
3′-3⅜″	6′ 0″×8″×4½″	6′ 0″×8″×4″ to 7′ 0″×9″×5″	1,936	1,900 to 2,460
2′-6″	5′ 0″×6″× 4″	5′ 0″×6″×4″ and 4′ 9″×7½″×4″	2,000	Maximum 2,200
2′-0″	4′ 0″×6″×4″	4′0″ × 6″ × 4″		

For light rails a larger number of sleepers are required per mile than for heavy rails. Where sleepers are sawn up in the forest and floated out it is customary to cut them about ¼ inch larger in breadth and depth and 3 to 6 inches longer than the required size to allow for loss due to wear and tear in floating. At points and crossings specially long sleepers are required, their number varying with the length of tongue rail and the angle of crossing. In the standard switch and crossing most in use the total number of sleepers would be about 42, of which 8 would be ordinary sleepers and 34 special sleepers of different lengths.

(3) WOODS EMPLOYED FOR SLEEPERS.

The Indian woods at present most used for sleepers are *sál*, deodar, and Burmese *pyinkado* (*Xylia dolabriformis*); teak has been a good deal used on some of the railways of the Indian Peninsula, and is a very durable sleeper wood, but it is now generally considered too valuable for extensive use. Various other woods are used more locally and to a smaller extent, the most important being, *Mesua ferrea*, *Bischofia javanica*, *Lagerstrœmia parviflora*, *Pterocarpus Marsupium*, *Hopea parviflora*, and *Terminalia tomentosa*. Of foreign woods, jarrah (*Eucalyptus marginata*) and other species of *Eucalyptus* from Australia, and creosoted pine (*Pinus sylvestris*) from Norway, are employed. It is impossible to come to any definite conclusion as to the respective merits of the different woods used, as the various railway administrations differ in their opinions. A good deal of con-

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fusion has no doubt been caused by the fact that inferior woods have from time to time been passed off as something better, thus giving a bad reputation to the genuine article which it is difficult to remove. In judging of the suitability of a wood for sleeper purposes it is necessary to take into account not only its durability, but also its capacity for resisting wear and tear. In Northern India deodar and *sál* are the woods most employed; of these the latter, if of good quality, is superior to the former in resisting wear and tear, but is much more liable to warp. As regards durability there is little to choose between the two: on the Oudh and Rohilkhund Railway, however, the *sál* obtained from Nepal is considered superior to deodar in durability as well as in resisting wear and tear. Teak is considered on most railways to be the best of all sleeper woods in every respect; it is, however, usually too expensive to employ on a large scale, and on some railways it is used only for bridge sleepers which have to be bedded on ironwork, or for points and crossings. *Xylia dolabriformis* has a high reputation and is extensively employed in Burma except on iron bridges, where teak is used. On the Bengal and North-Western Railway it is ranked equal with *sál* as the most durable sleeper wood, being considered superior to deodar, while on the Assam-Bengal Railway it also occupies the first place, being considered superior to *sál;* sleepers for these as well as for some other Indian Railways are obtained from Burma, where there are large supplies of this timber in places as yet unworked owing to their inaccessibility. The *Jamba* (*Xylia* sp.) of Bombay has not given satisfaction, and appears to be much inferior to the Burma wood in technical properties. The best indigenous sleeper wood in Assam is *Mesua ferrea*: it is an excellent wood, but is excessively hard and heavy, causing difficulty in conversion and extraction.

(4) CAUSES OF DETERIORATION IN SLEEPERS.

It may be said generally that the main causes of deterioration in sleepers are rot, climatic influences, and mechanical wear and tear. Insects play only a secondary part, and are seldom destructive except on little used sidings, where white-ants sometimes destroy the sleepers. The nature of the ballast used makes a great difference to the lasting power of a sleeper. The worst forms of ballast are clayey material which will not drain properly, soft decaying stone, and soft inferior kunker, which disintegrates into a clayey substance. Sleepers will last best in clean ballast of broken stones, the ballast having a depth of 8 to 12 inches below the sleeper to ensure good drainage, and completely embedding it to keep it steady. In damp climates and in moist badly-drained cuttings sleepers will naturally decay more quickly than in dry climates or on well drained soil, while most mechanical wear takes place on sharp curves and on lines where the traffic is heavy.

Various systems of antiseptic treatment have been proposed or adopted to prolong the life of railway sleepers; some of these are described on pages 288 to 297.

Most forms of impregnation, however, are not suited for hard closed-grained woods, while the softer woods are inferior in mechanical powers of resistance. Splitting may be prevented by bolting the ends or binding them with hoop-iron, while tarring helps to keep out moisture and prevent cracks and decay; the bolting or binding combined with tarring is carried out in Madras at a cost of $2\frac{1}{2}$ to 3 annas per sleeper. Soft-wood sleepers are made more lasting in America by having slabs of hard-wood "bearing-plates" inserted at the points where the chairs or rails rest on them, while successful experiments have recently been made in India in the use of hard-wood dowels or plugs let into sleepers of soft-wood, the rail spikes being driven into these dowels, which prevent the spikes from working loose.

(5) THE SUPPLY OF SLEEPERS.

The total length of railways in British India, including Native States, at the end of 1910 was 32,099 miles, of which 16,701 miles were of 5 feet 6 inches gauge, 13,530 miles of 3 feet $3\frac{3}{8}$ inches gauge, 1,436 miles of 2 feet 6 inches gauge, and 432 miles of 2 feet 0 inch gauge. During the five years 1906 to 1910 inclusive the average annual length of new line opened was 760 miles, and if this figure be accepted as an estimate of the mileage of new lines to be opened for the next few years, it will be readily understood that the quantity of sleepers required for new lines alone will be considerable, being probably some 15 lakhs of sleepers per annum, of which, however, a proportion would be of metal. In addition to this the number of renewals of wooden sleepers on existing lines would probably amount to at least 34 lakhs per annum, so that a total of well over 40 lakhs of wooden sleepers per annum would not be too high an estimate of the number for some years to come, should the present proportion of wood to metal sleepers continue.

It will be seen from these figures that the supply of the best kinds of sleepers from the Indian forests is by no means assured, particularly when it is considered that conversion into sleepers, and especially broad gauge sleepers is not as a rule so profitable as conversion into scantlings of various sizes, so that the more the demand for building timber increases the higher will be the cost of railway sleepers of the more durable kinds. It may, therefore, in time come about that other woods of less durable kinds will be more and more used for sleepers, particularly if these can be rendered more durable by impregnation or other means at a moderate cost: as a set-off against this there are still extensive tracts of forest which are at present too inaccessible to work at a profit for sleepers, but which may become more accessible as means of communication are improved.

(6) THE RESPECTIVE MERITS OF WOOD AND METAL SLEEPERS.

The scarcity of wood for sleepers has led to the extensive adoption of metal for the purpose, many of the Indian railways being laid, in part at least, with metal sleepers. Various forms have been suggested, but the two forms in general use at present are the trough sleeper, shaped like a shallow inverted trough made of iron or steel, and the pot-sleeper, consisting of two inverted iron pots supporting the rails and connected by an iron tie-rod. Metal sleepers, as compared with wooden sleepers, have various advantages and disadvantages, the chief of which may be summed up as follows:—

The main advantages of metal sleepers are, (1) they last longer than wooden sleepers; in locomotive yards, however, where wood or coal ashes abound, metal sleepers perish more quickly than wooden ones; (2) with metal sleepers the gauge has not the same tendency to spread that it has on wooden sleepers owing to the wear on the latter; (3) the ballasting of the line is less expensive for metal sleepers than for wood, as less ballast for drainage and for holding the sleepers is required.

The chief advantages of wooden sleepers are, (1) they have not the same tendency to shift on sharp curves and on stone ballast as metal sleepers, because wooden sleepers exert more friction on the ground ; (2) wooden sleepers are less liable to damage in transport than metal sleepers ; (3) in India wooden sleepers are cheaper than metal sleepers ; (4) wooden sleepers make a smoother running road than metal, thereby making travelling more comfortable and causing less wear and tear to the rolling-stock and to the rails ; (5) minor accidents, due to the breakage of sleepers, are less frequent where wood is used than where metal is employed ; (6) the cost of laying the line is cheaper in the case of wooden than in the case of metal sleepers; workmen dislike handling metal sleepers, as they have sharp corners, and become very hot on a hot day and very cold after a cold night ; they also jar badly in travelling, taking much trouble to separate, whereas wooden sleepers pack easily and give no trouble in unloading. Pot sleepers are unwieldy in shape and therefore difficult to handle ; they are too heavy a load for one strong man or two weakly ones. All these items add considerably to the cost of laying the line.

On the whole the advantages of the wooden sleeper far outweigh those of the metal one, because although the average life of the latter is probably not more than double that of the former, its cost is about double, so that the advantage of durability is neutralized by the disadvantage of costliness.

SECTION IV.—TIMBER USED IN CONTACT WITH WATER.

Under this head are included piles and posts for bridges, weirs, harbour works and similar constructions, water-wheels, well-curbs, water-pipes, sluice-gates, works for strengthening the banks of streams, wet-slides, booms, etc. Timber exposed to alternate wetting and drying is particularly liable to decay, and only durable timber should be employed : if the wood

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is kept constantly under water it lasts better than if exposed to occasional drying. Some woods, for example *Anogeissus latifolia* and *Schleichera trijuga*, do not last well under water, while others which are not ordinarily durable or are only moderately durable will last a long time in contact with water, and are therefore used in well construction and for water-troughs and similar purposes; among these may be mentioned *Bombax malabaricum*, *Boswellia serrata*, *Butea frondosa*, *Dillenia indica*, *Duabanga sonneratioides*, *Erythrina suberosa*, *Eugenia Jambolana*, *Ficus glomerata*, *F. religiosa*, *Mangifera indica*, *Phyllanthus Emblica*, *Populus euphratica*, *Terminalia Arjuna* and *T. belerica*. In addition to these many of the more durable timbers are largely used in contact with water, for example *Acacia arabica*, *Acacia Catechu*, *Artocarpus Chaplasha*, *A. Lakoocha*, *Bischofia javanica*, *Cassia Fistula*, *Cedrus Deodara*, *Chickrassia tabularis*, *Fagræa fragrans*, *Gmelina arborea*, *Heritiera minor*, *Lagerstræmia Flos-Reginæ*, *Mesua ferrea*, *Mimusops* spp., *Ougeinia dalbergioides*, *Pterocarpus dalbergioides*, *Shorea robusta*, *Tectona grandis*, and *Xylia dolabriformis*. For water-pipes *Borassus flabellifer* and *Phœnix sylvestris* are largely employed, while fascines for supporting the banks of streams and for other protective works are made of coppice shoots or of bamboos.

SECTION V.—TIMBER USED IN MACHINERY.

Although iron has replaced wood to a great extent in the manufacture of machinery, still in rural districts, including the greater part of India, wood is largely or entirely used for such purposes as sugar-mills, oil-presses, rice-pounders and husking apparatus, Persian wheels, spinning-wheels, hand-looms, cog-wheels, etc. Wood for machinery is subjected to much wear and tear, and should therefore be hard and tough. Some of the principal woods used for oil-presses, sugar-mills, and rice-pounders are *Acacia arabica*, *A. Catechu*, *A. modesta*, *Ægle Marmelos*, *Albizzia Lebbek*, *A. odoratissima*, *A. procera*, *Cassia Fistula*, *Chloroxylon Swietenia*, *Dalbergia Sissoo*, *Mimusops Elengi*, *M. hexandra*, *Odina Wodier*, *Schleichera trijuga*, *Shorea robusta*, *Soymida febrifuga*, *Tamarindus indica*, *Terminalia tomentosa*, *Vitex* spp., etc. For spinning-wheels various woods are used according to locality: in Bengal they are made of *sál* or *Anogeissus*

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latifolia, while in the Central Provinces the frame is made of teak, the wheel having a nave of *Ougeinia dalbergioides* and spokes of *Acacia Catechu*, of which the posts supporting the wheel are also made. Spinning and weaving machines in the Punjab are made of walnut, apricot, *Cotoneaster* and *Olea ferruginea*, while in Madras *Hardwickia binata* is often employed. In the United Provinces *sál* and *Adina cordifolia* are used for cog-wheels. The Persian wheels of the Punjab are largely made of *Acacia arabica*, and those of Ajmer-Merwara of *Acacia arabica*, *Anogeissus pendula* and *Dichrostachys cinerea*.

SECTION VI.—TIMBER USED FOR BOAT AND SHIP BUILDING.

1. *General.*

Timber used in ship-building is subjected to enormous strains and is employed under conditions which tax its durability to the utmost: for this reason it should be strong and elastic, durable, and free from defects and unsoundness, while its weight will depend on the part of the vessel for which it is intended, a heavy wood being preferable for the keel while for the upper parts a lighter wood is desirable.

The hulls of sea-going boats consist of a *keel*, with a strong framework of *ribs* on which the outer planks are nailed. The ribs are made of naturally bent wood known as *compass-timber*, *crooks*, or *bends*; these are sometimes artificially bent, but are then not so strong. In river boats there is usually no keel, the boats being flat-bottomed, while the framework is composed of *knees*, that is, curved pieces consisting of the main stem of a tree, with a branch making more or less a right angle with it: these knees are considerably further apart than the ribs of sea-going ships, while the degrees of curvature on the sides of river boats are not so varied as in sea-going boats.

Teak is the best ship-building timber in the world, not only on account of its durability, strength, and freedom from warping, but also because it does not corrode iron bolts and plates with which it comes in contact; for this reason it is largely used in the construction of iron-clads, for which purpose the best teak is exported to Europe. Lloyd's Register places teak in a class by itself, as being superior to all other timbers for ship-building. Oak, though otherwise an excellent ship-building timber, contains tannic acid which corrodes iron, and is therefore not so suitable as teak.

2. *Hulls.*

Some of the woods most largely used in India for the hulls of boats, other than dugouts, which will be dealt with below, are as follows :—

Acacia arabica : much used for ribs, stems, knees, keels and other parts of boats.

A. Catechu : ribs, knees, stems, keels of boats (Bombay).

Adina cordifolia : planking of river boats.

Albizzia Lebbek.

Amoora Rohituka : knees of boats (Chittagong).

Artocarpus Chaplasha : (Chittagong).

A. hirsuta : (West Coast of India).

A. integrifolia : (Madras).

Bassia latifolia.

B. longifolia : ships' keels and planking below the water line.

Berrya Ammonilla : (Burma and Madras).

Calophyllum Inophyllum : (Indian coast districts and Andamans).

C. polyanthum : (Chittagong).

Cassia Fistula.

Cedrela Toona.

Cedrus Deodara : chiefly planking (Punjab and Kashmir).

Chloroxylon Swietenia : (Madras).

Dalbergia latifolia : knee timbers.

D. Sissoo : largely used for boat-building, particularly for ribs and frame-works.

Dipterocarpus tuberculatus : (Burma).

D. turbinatus : knees, planks, etc. (Chittagong).

Erythrina indica : side and deck planks (Madras).

Eugenia Jambolana : chiefly deck-planking.

Fagræa fragrans : (Burma).

Fraxinus floribunda : (Kashmir).

Gmelina arborea.

Heritiera minor : much used for boat-building in Bengal.

Hopea odorata : (Burma).

H. parviflora : (Madras).

Juglans regia : decks and insides of cabins (Kashmir).

Lagerstrœmia Flos-Reginæ : (Burma and Chittagong).

L. hypoleuca : hull-planks, keels, etc. (Andamans).

L. lanceolata : one of the chief woods for ship and boat building on the West Coast of India.

L. parviflora.

Mangifera indica : chiefly used for side-planks and decks.

Melia indica.

Mimusops Elengi.

M. hexandra.

Ochrocarpus siamensis : (Burma).

Odina Wodier : ribs of boats.

Ougeinia dalbergioides : (Central Provinces).

Pentace burmanica : (Burma).

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Pentacme suavis : (Burma).

Pinus excelsa : (Kashmir).

Pinus longifolia.

Pterocarpus dalbergioides : hull-planks, keels, stem and stern posts, ribs, thwarts and deck-planking (Andamans).

P. Marsupium.

Pterospermum rubiginosum : (Travancore and Tinnevelly).

Salvadora oleoides : knee-timbers of boats (Sind and Punjab).

Shorea robusta.

Sonneratia apetala.

Tamarindus indica : side planks of boats (Madras).

Tectona grandis : the best known timber for ship-building ; largely used for ships and boats in India.

Terminalia Arjuna.

T. belerica.

T. tomentosa.

Xylia dolabriformis : keels of sea-going boats and boat-building in general.

3. *Masts and Spars.*

Timber for masts and spars should be long, straight, strong, and elastic, while lightness is also desirable. In Europe the best masts are obtained from slow-grown coniferous timber, while in India the chief woods used are *Alphonsea ventricosa* (Andamans), *Artocarpus Chaplasha* (Burma), *A. hirsuta* (Madras), *A. integrifolia* (Burma and Madras), *Calophyllum Inophyllum*, *C. polyanthum* (Chittagong), *C. spectabile* (Andamans), *C. tomentosum* (yields the celebrated " poon spars," (W. Coast), *Casuarina equisetifolia*, (Madras and Bombay), *Cedrela Toona* (Chittagong), *Cedrus Deodara* (Punjab), *Grewia tiliæfolia*, *Heritiera minor* (Bengal), *Homalium tomentosum* (Burma), *Lagerstrœmia Flos-Reginæ* (Chittagong and Burma), *L. lanceolata* (W. Coast), *Mesua ferrea* (Chittagong), *Parashorea stellata* (Burma), *Pentace burmanica* (Burma), *Pinus excelsa* (Kashmir), *Podocarpus neriifolia* (Andamans), *Polyalthia fragrans* (W. Coast), *Shorea robusta*, *Tectona grandis* (largely used), *Terminalia bialata* (Andamans). Large bamboos are also very commonly used.

4. *Oars and Helms.*

Oars should be made of straight-grained, strong and elastic wood, lightness being also necessary in the case of long oars ; for short paddles heavier woods are sometimes used, though there is an obvious disadvantage in having a paddle which will sink if dropped into the water. In many parts of India oars are made with shafts of bamboos, a blade of *sundri*, mango, teak or other wood being fixed on the end

The chief woods used for oars are *Artocarpus Chaplasha. A. integirfolia, A. Lakoocha, Berrya Ammonilla, Bischofia javanica, Bombax malabaricum* (oar-blades), *Casuarina equisetifolia, Cedrela Toona, Cedrus Deodara, Dalbergia Sissoo, Dipterocarpus tuberculatus, D. turbinatus, Duabanga sonneratioides, Eugenia Jambolana, Fraxinus floribunda, Gmelina arborea, Grewia* spp., *Gyrocarpus Jacquini, Heritiera minor, Hopea odorata, H. parviflora, Lagerstrœmia Flos-Reginæ, L. parviflora, Mangifera indica, Melia indica, Michelia Champaca, Ougeinia dalbergioides, Pentace burmanica, Pinus excelsa, P. longifolia, Podocarpus neriifolia, Pterocarpus Marsupium, Shorea robusta, Tectona grandis, Terminalia Arjuna, T. tomentosa, Vitex glabrata.*

Most of the species used for oars and masts are also used for helms, for which a strong and elastic wood is required, the strain on this part of the boat being considerable.

5. *Dugouts and other Special Forms of Boats.*

Dugouts are boats made by hollowing out a single log, and are largely used on many of the rivers of India and Burma : they are of all sizes, from small skiffs capable of seating one or two persons to large boats carrying merchandise, the capacity of the latter being often increased by having a dugout bottom surmounted by sides of planking.

The common method of manufacturing dugouts is as follows :—

A straight log is selected and the sapwood trimmed off ; the log is then placed on billets to keep it off the ground, care being taken to have the straightest surface underneath, to ensure that the bottom of the boat is straight. The log is then hollowed out with an adze, the breadth of the hollow at the top being about one-fifth of the girth of the log, though it is often made narrower in the centre than at the ends : the ends of the log are left solid for two or three feet, and are afterwards shaped to a point. To prevent the sides of the boat from being made too thin it is sometimes customary to bore small holes one inch deep at intervals along the sides of the log before commencing the hollowing or during the process of hollowing ; these holes, which act as guides to the thickness of the boat, are afterwards filled up. When the hollowing is completed the boat is turned upside down over a fire, which is kept low and steady, and cross-pieces (*thwarts*) are inserted to keep the sides apart; in Burma this opening out is further assisted by attaching ropes by means of wooden hooks to the sides of the hollowed log, these ropes being stretched tight to either side, tied to wooden pegs driven into the ground, and wetted to cause shrinkage and tension. To prevent cracking the opening out should be done gradually as the hollowing proceeds, and as a rule the wood employed should either be green or else be well soaked before use. Dugouts are often kept under water when not in use, to prevent the cracking which is liable to occur owing to exposure to the sun. On some rivers the ends of the hollowed log are trimmed flat and boards are nailed over them; this is necessary when there is an unsound heart to the log, but where timber is plentiful logs can be specially selected for their soundness, and this method need not be employed.

Some of the principal woods employed for dugouts are *Adina cordifolia*, *Albizzia procera*, *A. stipulata*, *Amoora Rohituka*, *Anthocephalus Cadamba*, *Artocarpus Chaplasha*, *A. hirsuta*, *A. Lakoocha*, *Bassia latifolia*, *Bombax malabaricum*, *Cedrela Toona*, *Dipterocarpus alatus*, *D. tuberculatus*, *D. turbinatus*, *Duabanga sonneratioides*, *Eugenia Jambolana*, *Gmelina arborea*, *Hopea odorata*, *H. parviflora*, *Lagerstrœmia Flos-Reginæ*, *L. tomentosa*, *Mangifera indica*, *Michelia Champaca*, *Ochrocarpus siamensis*, *Odina Wodier*, *Shorea robusta*, *Tectona grandis*, *Terminalia belerica*, *T. Chebula*, *T. myriocarpa*, *T. paniculata*, *T. tomentosa*, *Tetrameles nudiflora*.

Sampans are flat-bottomed boats largely used in Chittagong, Rangoon, and other ports; the largest are some 50 feet long by 8 feet broad, and draw only 12 to 18 inches of water. They are commonly made of planks of *Cedrela Toona* ¾ of an inch thick nailed to knees of the same wood; less frequently the planks are made of *Gmelina arborea* or *Terminalia belerica*. Among other local forms of boats may be mentioned the river *coracles* (Tamil *Parasal*) of Madras and elsewhere, made of a framework of split bamboo covered with leather, and the Madras *catamarans*, usually made of *Erythrina indica*, *Ailanthus excelsa*, *Givotia rottleriformis*, *Gyrocarpus Jacquini*, or *Terminalia belerica*. The *surf-boats* of Madras are chiefly made of *Berrya Ammonilla*, a tough wood which can stand the severe strains to which these boats are subjected.

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SECTION VII.—TIMBER USED IN JOINERY AND CABINET-MAKING.

By joinery is meant the fitting together of the smaller and finer classes of converted wood, usually for interior work such as doors, windows, panelling, staircases, and other fittings. For these purposes, as well as for furniture, well-seasoned and easily worked wood is required which does not warp or split and which holds well at the joints. For ornamental purposes a wood of good colour and grain, which takes a fine polish, is desirable. In the case of valuable ornamental woods *veneers*, or thin sheets of wood, are glued to less valuable woods. These veneers, which vary from $\frac{1}{4}$ to $\frac{1}{150}$ of an inch in thickness, are prepared by machinery, either by fine circular saws or by special knives acting on steamed wood, and are sometimes afterwards pressed to give them a good surface.

India possesses some furniture woods which are highly valued in Europe, for example *Dalbergia latifolia* (Blackwood, or Rosewood of Southern India), *Juglans regia* (Walnut), *Tectona grandis* (Teak), *Albizzia Lebbek* (East Indian Walnut), *Pterocarpus dalbergioides* (Padauk, or Andamans Redwood), *Chloroxylon Swietenia* (Satinwood), *Diospyros Kurzii* (Andamans Marblewood) and *D. Ebenum* (Ebony): the last-named is exported from Ceylon, but trees of sufficiently large dimensions are not plentiful enough in India to afford steady supplies. There are also other woods which would be highly valued in Europe for ornamental purposes if they were better known. Among the woods used in India for furniture and joinery may be mentioned the following:—

Abies Pindrow: used in the Himalayas for rough furniture.

Acacia arabica: used in the Punjab for bedstead legs.

Acacia Catechu: bedsteads and other articles of furniture.

Adenanthera pavonina: used for furniture and cabinet-making in Southern India and the Andamans.

Adina cordifolia: a yellow even-grained wood, frequently used for furniture.

Albizzia amara: a handsome furniture wood, brown or red, beautifully veined or mottled.

Albizzia Lebbek: the "East Indian Walnut" is a well-known furniture wood, the burrs being particularly valuable.

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Albizzia mollis: a handsome furniture wood, dark brown, beautifully mottled.

Albizzia odoratissima: a dark brown wood, with darker streaks, used for side-pieces of bedsteads and other articles of furniture.

Artocarpus Chaplasha: one of the best of furniture woods; yellowish-brown in colour and of handsome grain.

Artocarpus hirsuta: much used for furniture on the West Coast of India.

Artocarpus integrifolia: a good wood for furniture, cabinet-making, and carpentry, sometimes exported to Europe.

Artocarpus Lakoocha: used for furniture, but not so good as Artocarpus Chaplasha.

Bassia latifolia: used for furniture in the Central Provinces and Madras.

Cæsalpinia Sappan: a pretty wood, suitable for inlaying and small fancy work.

Calophyllum Inophyllum: good for cabinet-making.

Carallia integerrima: a particularly handsome wood when cut on a radial section to show the silver grain, in which respect it somewhat resembles oak; easily worked, takes a good polish, and is suitable for furniture, cabinet-work, panelling, etc. Used for furniture and cabinet-making in Southern India and Burma.

Cedrela Toona: largely used for furniture, cabinet-making, boxes, etc. The wood is of a handsome red colour and is easily worked, but is not strong and is somewhat liable to be attacked by small boring beetles.

Cedrus Deodara: much used in the Himalayas and adjacent tracts for rough furniture such as tables, benches, etc.

Chickrassia tabularis: a very handsome furniture wood, taking a good polish; should not be used unless well seasoned, as it is liable to shrink when not thoroughly seasoned.

Chloroxylon Swietenia: "satin-wood" is a well-known yellow wood, much esteemed for furniture and cabinet-making, pieces showing a good "figury" grain fetch a high price.

Cinnamomum Cecidodaphne a wood highly scented with camphor, and suitable for cabinet-work.

Cinnamomum glanduliferum: used for furniture and cabinet-making in Bengal and Assam, strongly scented of camphor.

Cocos nucifera: cocoanut wood, the "porcupine wood" of commerce, makes handsome furniture.

Cordia Macleodii: a handsome brown mottled wood, suitable for furniture.

Cordia vestita: another handsome brown mottled wood with a figured grain, very suitable for furniture and cabinet work.

Cupressus torulosa: used in the Himalayas for furniture and cabinet-making.

Dalbergia cultrata: a dark purplish-black wood, which should be suitable for ornamental furniture.

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Dalbergia latifolia : this is the famous Bombay blackwood or rosewood of Southern India, a very hard dark purple wood with black streaks, a valuable furniture wood, in considerable demand in the European market.

Dalbergia Oliveri : a handsome Upper Burma wood, hard and of a red colour with darker red streaks, suitable for high-class ornamental furniture.

Dalbergia Sissoo : , an excellent furniture wood, largely used in Northern India, a hard brown wood with darker streaks, capable of taking a fine polish. A very good wood for camp furniture.

Diospyros Ebenum : The ebony is well-known as a wood suitable for fine ornamental furniture and cabinet work.

Diospyros Kurzii : the "marble wood" of the Andamans, a handsome variegated ebony suitable for ornamental furniture and cabinet work.

Diospyros Melanoxylon : used for furniture in Bengal and the Central Provinces.

Diospyros tomentosa : used for furniture in the United Provinces.

Dipterocarpus tuberculatus : used for rough articles of furniture and joinery in Burma.

Fraxinus floribunda : used for furniture in the Punjab.

Glochidion neilgherrense : a red, fairly hard wood with a good silver grain, used for cabinet work.

Gmelina arborea : a useful wood for furniture, cabinet-making and joinery, light coloured, easily worked and does not warp or split.

Hardwickia binata : used for ornamental work, very hard and heavy, dark red to nearly black.

Heritiera minor : used for furniture in Bengal.

Juglans regia : the walnut is probably the most valuable furniture wood in the Himalayas, the burrs in particular being of special value for veneering purposes.

Lagerstrœmia Flos-Reginœ : used for ordinary furniture in Burma, Assam, etc.

Mangifera indica : used for ordinary cheap furniture.

Melia Azedarach : a red rather soft wood which makes good furniture and cabinet work.

Melia indica : a hard red wood somewhat resembling mahogany and used for furniture.

Michelia Champaca : a soft, light olive brown wood used for ordinary furniture and for boxes.

Michelia excelsa : used for furniture in Darjeeling.

Morus alba : a good furniture wood.

Morus indica : a good wood, but not usually obtainable in any size.

Morus lævigata : a handsome yellowish-brown or reddish-brown wood, very suitable for furniture.

Morus serrata : an excellent wood for furniture and cabinet work, much in use in the Himalayas.

Murraya exotica : a light yellow close-grained wood, somewhat resembling boxwood and suitable for cabinet work.

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Olea ferruginea : a brown wood of various shades, often prettily marked, suitable for inlaying, used for furniture in the Punjab.

Ougeinia dalbergioides : A good strong furniture wood.

Pentace burmanica : a pretty wood, easily worked, and good for cabinet-making, boxes, etc.

Pentacme suavis : used for strong articles of furniture in Burma.

Picea Morinda : used in the Himalayas for rough furniture.

Pinus excelsa : used for ordinary furniture in the Himalayas and adjacent tracts.

Pinus longifolia : used for rough furniture and general carpentry, not so good as *Pinus excelsa*.

Pistacia integerrima : a handsome furniture wood suitable for all kinds of ornamental work.

Podocarpus neriifolia : an even-grained fairly soft wood, easily worked and excellent for carpentry and ordinary cabinet work.

Populus euphratica : used for common furniture in Sind.

Prunus Puddum : used for furniture in Darjeeling, a red wood with a pretty silver grain, suitable for ornamental furniture.

Pterocarpus dalbergioides : the Andamans padauk is a wood of a rich red colour, used for high classes of furniture, panelling, cabinet work, piano cases, parquetry, etc. Unless polished or otherwise protected from the atmosphere it is apt to lose colour.

Pterocarpus macrocarpus : the Burma padauk is somewhat like Andamans padauk, but has not such a rich red colour. It has been very well reported on as a furniture wood, being particularly suited for camp furniture ; it turns and works well and takes a fine polish. It has recently been successfully tried in the manufacture of billiard tables.

Pterocarpus Marsupium : a yellowish brown wood with darker streaks, much used for furniture in Central and Southern India.

Pterocarpus santalinus : used for legs of bedsteads in Madras, also used for small fancy work, such as picture-frames, etc.

Rhus Cotinus : an ornamental wood, used for inlaying and cabinet work, as well as for fine work such as picture-frames.

Santalum album : used for fine carved cabinet work.

Shorea assamica : used for furniture and cabinet-making in Assam.

Shorea obtusa : used for strong articles of furniture in Burma.

Shorea robusta : used for strong articles of furniture.

Soymida febrifuga : a very hard dark reddish brown wood, used for furniture.

Tecoma undulata : used for bedsteads in Marwar, a rather handsome wood for furniture and cabinet work.

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Tectona grandis : teak is one of the most largely used woods for furniture and cabinet-making of all kinds, being easily worked and taking a good polish.

Terminalia bialata : a handsome mottled wood, which makes good furniture.

Terminalia tomentosa : used for bedsteads and coarser kinds of furniture, such as benches, etc.

Thespesia populnea : a hard dark red wood, used in Southern India for benches, legs of bedsteads and cabinet-making.

Ulmus Wallichiana : used for furniture in the Punjab Himalayas, a handsome wood with a pretty silver-grain.

Zizyphus Jujuba : bedstead legs and other articles of furniture.

SECTION VIII.—TIMBER USED IN CART AND CARRIAGE MAKING.

For the framework of carts and carriages a fairly light wood is required, but this should be strong and elastic. The most important parts of a cart or carriage are the wheels, the axle, and the shafts. An ordinary wheel consists of a *nave* (*hub*), *spokes* and *felloes*, and is usually encircled by a metal tyre. The *nave* has to bear great strain, and should therefore be of hard tough wood, free from defects and without sapwood; it should be hard enough to prevent the spokes from working loose in the holes (*mortises*) cut for their insertion in the nave. The woods most commonly used for naves are *Acacia arabica*, *A. Catechu*, *A. leucophlœa*, *Albizzia Lebbek*, *A. odoratissima*, *A. procera*, *Anogeissus latifolia*, *Artocarpus integrifolia*, *Berrya Ammonilla*, *Cassia Fistula*, *Chloroxylon Swietenia*, *Dalbergia latifolia*, *D. Sissoo*, *Hardwickia binata*, *Mesua ferrea*, *Ougeinia dalbergioides*, *Pterocarpus dalbergioides*, *P. macrocarpus*, *P. Marsupium*, *Schleichera trijuga*, *Shorea robusta*, *Tectona grandis*, *Xylia dolabriformis*.

Spokes should be made of well-seasoned straight-grained wood, free from defects and unsoundness, and without sapwood; the wood should be tough and elastic, not liable to warp, split, or shrink, and hard enough not to work loose in the mortises of the nave and felloes. The chief woods for spokes are *Acacia arabica*, *A. Catechu*, *Albizzia Lebbek*, *A. odoratissima*, *A. procera*, *Artocarpus hirsuta*, *A. integrifolia*, *Berrya Ammonilla*, *Carapa moluccensis*, *Dalbergia latifolia*, *D. Sissoo*, *Diospyros Melanoxylon*, *Hardwickia binata*, *Heritiera minor*, *Lagerstrœmia Flos-Reginæ*, *Odina*

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Wodier, *Ougeinia dalbergioides*, *Prosopis spicigera*, *Pterocarpus dalbergioides*, *P. macrocarpus*, *P. Marsupium*, *Shorea robusta*, *Tectona grandis*, *Thespesia populnea*, *Xylia dolabriformis*.

Felloes are subjected to much crushing, as well as to alternations of wet and dryness; they should therefore be made of hard, strong, elastic, and durable wood, free from defects and unsoundness, and without any sapwood, while the wood should not be liable to expansion or contraction with varying conditions of moisture. The fibres should be cut through as little as possible, hence naturally curved timber is the most suitable, and where this is not obtainable the felloes should be cut from split sections of wood in such a way that the annual rings lie as much as possible in the plane of the wheel, that is, the flat sides of the felloe should show a tangential section. The woods most in use for felloes in India are *Acacia arabica*, *A. Catechu*, *A. leucophlœa*, *Albizzia Lebbek*, *A. odoratissima*, *A. procera*, *Anogeissus latifolia*, *Berrya Ammonilla*, *Casuarina equisetifolia*, *Chloroxylon Swietenia*, *Dalbergia latifolia*, *D. Sissoo*, *Lagerstrœmia Flos-Reginæ*, *Melia indica*, *Ougeinia dalbergioides*, *Pterocarpus dalbergioides*, *P. macrocarpus*, *P. Marsupium*, *Schleichera trijuga*, *Shorea robusta*, *Tectona grandis*, *Xylia dolabriformis*. For the wheels of light carriages bent rims are sometimes employed, these being made of one piece of split wood, previously steamed.

In some parts of India, particularly in outlying rural districts, solid wheels are made of one piece of wood, or more commonly of three pieces held together by an iron tyre, or by iron clamps or plates. Woods used for this purpose are teak, *Acacia arabica*, *Anogeissus latifolia*, *Bursera serrata*, *Careya arborea*, *Hopea odorata*, *Mangifera indica*, *M. sylvatica*, *Ochrocarpus siamensis*, *Pterocarpus macrocarpus*, *Shorea robusta*, *Tectona grandis*, *Terminalia tomentosa*, *Tetrameles nudiflora* and *Xylia dolabriformis*. These solid wheels are to be found in parts of Madras, Bengal, Burma and Bombay.

In Kāshmir the solid wheels of small country trucks are made of *Celtis australis*, *Cratægus Oxyacantha*, *Pinus excelsa*, *Prunus Padus*, and *Taxus baccata*.

Shafts are made of straight-grained split wood, which should be tough, elastic, and free from defects, great strength being particularly necessary for carriage and buggy shafts owing to their thinness. The principal woods used for shafts

are *Acacia arabica, A. Catechu, Anogeissus latifolia, Berrya Ammonilla, Bridelia retusa, Chloroxylon Swietenia, Dalbergia cultrata, Diosypyros Melanoxylon, Grewia tiliæfolia, G. vestita, Hardwickia binata, Heritiera minor, Homalium tomentosum, Mesua ferrea, Ougeinia dalbergioides, Pentacme suavis, Pterocarpus dalbergioides, P. Macrocarpus, P. Marsupium, Shorea obtusa, S. robusta, S. Talura, S. Tumbuggaia, Strychnos potatorum, Tectona grandis, Terminalia bialata, T. Chebula, T. myriocarpa, T. tomentosa, Thespesia populnea, Xylia dolabriformis.*

For carriage and buggy shafts the chief woods used are *Acacia arabica, Diospyros Melanoxylon, Heritiera minor, Pterocarpus macrocarpus, Tectona grandis,* and *Xylia dolabriformis,* while bamboos are largely employed for buggy shafts.

Axles are made of tough hard wood; most of the woods suitable for shafts are used, some of the best woods being *Acacia arabica, A. Catechu, Anogeissus latifolia, Dalbergia Sissoo, Heritiera minor, Schleichera trijuga, Shorea robusta, Terminalia Chebula,* and *Xylia dolabriformis.*

Yokes are made of a large variety of woods, one of the most generally used species being *Gmelina arborea.* The aërial roots of *Ficus bengalensis* are also used, while most of the woods employed for shafts are also suitable for *yokes.* Light woods are preferred.

The *framework* of carts is constructed of a variety of woods, tough hard woods being used where there is much strain or friction. Teak is perhaps the most universally suitable wood for the purpose. In the hills of Madras small rough carts made of bamboo (*Bambusa arundinacea*), with axles of *Anogeissus latifolia* and solid wheels of *Acacia arabica,* are used. For light carriages one of the most suitable woods for the upper parts is *Gmelina arborea,* owing to its lightness, freedom from warping and splitting, the ease with which it can be worked, and the readiness with which it takes paint and varnish. For the framework of carriages *Dalbergia Sissoo* is one of the best woods.

Railway carriages and waggons.—Teak timber is largely used for the construction of railway carriages and wagons in India and Europe, while in America Andaman *padauk* (*Pterocarpus dalbergioides*) is largely used for the better class of railway carriages; for such work it is advisable to have a wood which will not splinter in case of railway accidents, in which respect padauk is perhaps superior to teak. *Babul*

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(*Acacia arabica*) is used for the packings of buffers, *Sál* and *Pterocarpus Marsupium* to some extent for railway waggon construction, and *Xylia dolabriformis* for bolsters for timber-trucks, bogie frames and other purposes for which great strength is required.

Gun carriages.—Timber used in the manufacture of gun-carriages is subjected to more strain and wear than that employed for any other form of carriage-building, and only the very strongest woods are suitable. The Burma *padauk* (*Pterocarpus macrocarpus*) has been put to more uses than any other wood in the manufacture of gun-carriages, both for wheel-work and for other purposes. The Andaman *padauk* (*P. dalbergioïdes*) was formerly used, but has to some extent been supplanted by the Burma *padauk.* For wheel-work and general construction *Dalbergia latifolia* and *D. Sissoo* are much used. *Acacia arabica* was formerly in more demand for ordnance work than it is now. Among woods which have been used, but are not commonly employed, are *Hopea parviflora*, *Lagerstrœmia Flos-Reginæ*, and *Thespesia populnea.* Teak and *sál* are used in the construction of transport waggons and other ordnance work.

SECTION IX.—VARIOUS USES OF SPLIT WOOD.

1. *Coopers' Wood.*

Under coopers' wood is included all wood employed for making barrels, casks, tubs, and similar vessels for holding liquids or dry goods. The most important class of coopers' wood is that used in the manufacture of casks for holding liquors such as beer, wine, etc.; these are subjected to rough treatment during transport, and should therefore be as strong and durable as possible, while the wood should also be water-tight, and thus be capable of retaining liquids without leakage, and should not be too heavy. Further requisites are straightness of grain and freedom from knots and other defects, while the wood should contain no substance which would give an undesirable taste, odour, or colour to the liquid.

Casks are composed of three parts, *side-staves*, *head-pieces*, and *hoops.* The side-staves are thinner and narrower at their ends, the centre being broader to allow for the bulging sides of the cask. The head-pieces are flat or in large

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casks slightly curved inwards to withstand the pressure of the liquid : they are firmly dovetailed together. The hoops are made of iron, or in more temporary casks of split coppice shoots of various species of trees.

In Europe the chief wood used for cask-staves is oak, though other woods are used for inferior casks, particularly those for holding dry goods. The staves are manufactured either by machinery or by hand : in the latter case the wood is split into staves when newly felled, this being usually done in the forest by means of a special cleaving tool, another shaving implement being used for the rough fashioning of the staves to the proper shape. The splitting is done in a radial direction, there being less leakage from wood so split than from wood split tangentially : the staves may either be partly cut to a curved shape or be afterwards bent to the required curve. Staves require long seasoning before they are ready for use, and have to be further trimmed and shaped by the cooper.

For dry goods such as sugar, salt, etc., barrels are often made of one thin sheet of wood after the manner of a sieve-frame; these sheets are planed off by means of a long blade which comes in contact with a round log of wood, previously well steamed, revolving on a horizontal axis.

Several Indian woods have been tried in the breweries for the manufacture of beer-casks, those which have proved most successful being *Grewia tiliæfolia*, *G. vestita*, *Alnus nepalensis* and *Ougeinia dalbergioides*; the only objection to the last named is its weight. *Quercus dilatata* has been found suitable, but *Q. incana* is useless owing to its tendency to split and warp. In Burma *Q. semiserrata* has been found suitable for beer-casks, but the difficulties of extraction have hitherto rendered its price prohibitive. Teak is a good wood for beer-casks, but owing to the oil it contains it is apt to give a taste to the liquor unless it is enamelled inside. Among woods which have been found fairly suitable are *Albizzia procera*, *Dalbergia Sissoo*, and *Lagerstrœmia hypoleuca*. *Sál* is used for large storage vats, but is not suitable for beer-casks as the staves are apt to warp and split.

The following are some of the chief Indian woods used for cooperage in general, such as tubs, buckets, casks, etc. :—

Acacia arabica.
Adina cordifolia.
Æsculus indica.
Albizzia Lebbek.
A. odoratissima.
A. stipulata.

Artocarpus Chaplasha.
A. hirsuta.
A. integrifolia.
Bombax malabaricum (oil-casks).
Boswellia serrata.
Calophyllum tomentosum.
Cedrela Toona.
Chickrassia tabularis.
Dalbergia latifolia.
D. Sissoo.
Dipterocarpus tuberculatus.
Duabanga sonneratioides.
Dysoxylum malabaricum.
Ficus glomerata.
Gmelina arborea.
Grewia tiliæfolia.
Lagerstræmia lanceolata.
L. parviflora.
Mangifera indica.
Odina Wodier.
Ougeinia dalbergioides.
Pinus longifolia.
Polyalthia longifolia.
Pterocarpus Marsupium.
Shorea robusta.
Tectona grandis.
Terminalia belerica.
Tetrameles nudiflora (oil-casks).
Trewia nudiflora.

2. *Trenails and Pegs.*

Trenails are large wooden pegs of different sizes up to 28 inches long and 3 inches thick. The large sizes are used in ship-building and are usually made of teak ; the smaller sizes are employed in joinery and cabinet-making in place of nails, while small pegs are used by shoemakers. Wood for these purposes should be straight-grained, and hard enough to resist being flattened out when hammered in.

3. *Shoulder-Poles, Spear-Shafts, Bows, and Fishing Rods.*

These are usually made from split wood, although bamboos are also largely employed, particularly for fishing-rods and lance-shafts, the latter being made of straight solid bamboos cut in the second or third year of growth, or even later. For all these purposes the wood should be straight-grained, tough and elastic.

For *shoulder-poles* some of the principal woods used are *Anogeissus latifolia*, *A. pendula*, *Capparis aphylla*, *Cotoneaster bacillaris*, *Diospyros Melanoxylon*, *D. tomentosa*, *Fraxinus floribunda*, *F. xanthoxyloides*, *Grewia* spp., *Ougeinia dalbergioides*, *Quercus dilatata*, *Taxus baccata*, *Tecoma undulata* and various bamboos.

Spear-shafts are made of *Acacia Catechu*, *Areca Catechu*, *Berrya Ammonilla*, *Cocos nucifera*, *Dalbergia cultrata*, *Dolichandrone stipulata*, *Grewia* spp., *Psidium Guava*, and other tough woods and various bamboos.

Bows are made of *Acacia Catechu* (Burma), *Alophyllus Cobbe* (Veddas), *Aquilaria Agallocha* (Karens), *Areca Catechu*, *Bauhinia racemosa* (Shan cross-bows), *Berrya Ammonilla* (Karens), *Dalbergia cultrata* (Burma), *Garcinia speciosa* (Andamans), *Grewia* spp., *Parrotia Jacquemontiana* (Punjab Himalayas), *Pentacme suavis* (Burma), *Taxus baccata* (bows for archery in Europe), *Xylia dolabriformis* (Burma), and several kinds of bamboos, arrows being made of various reeds and bamboos.

Fishing-rods.—Wood for fishing-rods requires to be straight-grained, tough and elastic, with sufficient stiffness to enable it to recover its straightness after a strain. Fishing rods in India are made of *Caryota urens* and of several kinds of bamboos, the "ringal" (*Arundinaria* spp.) rods of the Himalayas being well known. Samples of *Homalium tomentosum*, *Berrya Ammonilla*, *Pterocarpus macrocarpus*, *Acacia Catechu*, *Dillenia pentagyna*, *Grewia tiliæfolia* and *Lagerstrœmia lanceolata* were recently sent to a London firm for trial in the manufacture of fishing-rods, but of these the only one which gave any promise was *Homalium tomentosum*; the specimen, however, was too full of cracks to be of any use.

SECTION X.—WOOD USED FOR CARVING AND TURNING.

Woods for carving may be divided into two classes, first, those employed for carving into models, domestic utensils, etc., where an even-grained easily cut wood which will not warp or split is required, and second, those employed for ornamental carving, where in addition to being even-grained and fairly close-textured, the wood should be ornamental. Similarly for turning purposes woods may be divided into those fashioned into domestic utensils (milk-jars, cups, etc.) requiring an even-grained wood not liable to warp or split, and those used for the finer articles of ornamental turnery. There are a large number of Indian woods employed or suited for carving or turning of different kinds, of which the following will suffice as examples:—

Acacia arabica: carving and turning.
A. Catechu: ditto.
A. leucophlœa: turning.

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Acer spp. : turned into drinking-cups.

Adina cordifolia : grain-measures, etc.

Æsculus indica : domestic utensils (plates, cups, etc.)

Albizzia Lebbek : ornamental carving.

A. stipulata : bowls, spoons, etc.

Alstonia scholaris : carved images (Burma).

Artocarpus spp. : turning.

Bassia latifolia : cups and other utensils.

Bœhmeria rugulosa : much used for carving and turning into bowls, cups, plates, spoons, etc.

Boswellia serrata : carved into toys, spoons, etc.

Buxus sempervirens : a valuable wood for fine carving and turning (chess-men, small boxes, etc.)

Cassia Fistula : a good wood for turnery.

Cedrela Toona : much used for ornamental carving (picture-frames, tables, etc.), in Northern India.

Celtis australis : spoons and cups (Kashmir).

Chloroxylon Swietenia : much used for turning, and sometimes for carving.

Cratæva religiosa : carved into models, and used for turning.

Dalbergia latifolia : ornamental carving and turning, bowls, jars, grain-measures and other utensils.

D. Sissoo : much used for carving, and a good wood for turning.

Diospyros Ebenum : Ebony is much used for fine carving and turning.

D. Melanoxylon : carving and turning.

D. tomentosa : ditto.

Givotia rottleriformis : carved into figures, imitation fruit, etc., which are lacquered and painted.

Gmelina arborea : carved images, grain-measures, etc.

Holarrhena antidysenterica : much used for carving into small articles like paper-knives, picture-frames, spoons, forks, etc. ; also used for turning.

Juglans regia : ornamental carving ; also used for grain-measures and other utensils.

Melanorrhœa usitata : turning.

Melia indica : carved into images, being one of the sacred woods of the Hindus.

Morus spp. : carving and turning.

Odina Wodier : bowls, jars and other utensils.

Olea ferruginea : a good wood for turning.

Pistacia integerrima : ornamental carving.

Populus euphratica: used for turning in Sind and Baluchistan.

Pterocarpus dalbergioides: ornamental carving and turning.

P. macrocarpus: turning.

P. Marsupium: ditto.

P. santalinus: used for ornamental carving, images sold in temples, picture-frames, etc.

Santalum album: used for the well-known sandalwood carvings of Mysore, and also for fine turnery.

Stephegyne parvifolia: cups, plates, spoons, etc.

Tamarindus indica: very good for turning.

Tamarix articulata: turning.

T. gallica: turning.

Tecoma undulata: carving and turning, bowls and other utensils.

Tectona grandis: teak is largely used for carving, the well-known Burmese carved work being executed in this wood: also used for turning, and making jars, bowls, etc.

Wrightia tinctoria: carved into cups, spoons, etc., and much used for turning.

W. tomentosa: carved into cups, spoons, etc., and much used for turning.

Zizyphus Jujuba: turning.

SECTION XI.—WOOD USED FOR ENGRAVING.

Engravers' wood is used for preparing blocks for wood-cuts in printing; for this purpose the wood requires to be perfectly even-grained and so close in texture that it will not absorb inks and colours unevenly or too freely, while it should not be liable to warp or split, and should be so hard that the sharpest edges carved on it will not get destroyed by the pressure to which it is subjected in the press. Boxwood (*Buxus sempervirens*) is superior to all other woods for engraving, though for rough wood-cuts other even-grained woods are suitable. Among possible substitutes for boxwood may be mentioned many of the *Rubiaceæ* (*Randia* spp., *Gardenia* spp., *Ixora parviflora*, *Canthium* spp., *Wrightia tinctoria*, *W. tomentosa*), and a few of the *Rutaceæ* (*Limonia acidissima*, *Murraya exotica*, and *Atalantia monophylla*).

In parts of Bombay and Sind carved dies for stamping coloured patterns on cloth are made of *Acacia arabica*.

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SECTION XII.—WOOD USED FOR LEAD PENCILS.

Wood for lead-pencils should be straight-grained and even-textured, easily cut, and free from knots and other defects. The principal wood from which lead-pencils are made,—popularly known as cedar,—is a species of Juniper (*Juniperus virginiana*), found in the United States and Canada. Probably the best Indian wood for pencils is *Juniperus macropoda*. Some woods have lately been tested at a pencil factory in Calcutta, and of these *Cupressus torulosa, Cedrus Deodara, Podocarpus neriifolia, Pinus excelsa, P. longifolia and Wrightia tomentosa* were pronounced suitable for pencils, though rather tough, and the first three for penholders. For the latter purpose *Taxus baccata* was also found to be a useful wood.

SECTION XIII.—WOOD USED FOR MATCH MANUFACTURE.

General.—The match industry in India may be said to be as yet in its infancy. Some match factories have been in operation for years, others have recently been started, and the establishment of others is contemplated. Considering the abundance of suitable woods, there should be a successful future in store for the industry in India, provided the sites of the factories are well chosen and the factories themselves are properly managed. It is estimated that if India were to manufacture all the matches she now imports, some 70 large match factories would be required.

Methods of match manufacture.—Perhaps the most primitive method of making matches is by means of a splitting machine worked by hand like an ordinary tobacco-cutter, the wood being first sawn into blocks. This process is also carried out on a larger scale by machinery. Some matches are made with a shaving machine, which shaves with the grain of the wood from sawn blocks ; some are cut entirely with saws. Shaped splints, that is, of round, oval, square, or ribbed section, are made by feeding splints through the holes of a shaping iron : for this purpose the wood should be stored till thoroughly dry before use, and then steamed to allow the splints to pass through the shaping holes.

Method best adapted for India.—Any method of match manufacture which requires seasoned wood is unsuited for most parts of India, because many of the soft white woods become discoloured while dry-seasoning in the log or in large planks, and because such woods are extremely liable to the attacks of boring insects if kept stored. For India the peeling method of manufacture, in which green wood is used, is the most suitable one. This method is much cheaper than the splitting and shaping methods, the work is more expeditious, the machinery occupies less space, and less motive power is required. The peeling method consists in placing a round billet of wood in a machine like a turning lathe and shaving off, with a long fixed knife-blade, a continuous sheet of veneer the thickness of a match. These veneers are then passed through a guillotine which cuts match splints from them with great rapidity. The veneer for match-boxes is made by similar peeling machines. This method of manufacture is the one employed by all the chief existing match factories in India.

In the peeling process, since only green wood in the round is employed, the sooner it can be used after felling the better, and it should be transported if possible with bark on, to prevent drying. If it cannot be obtained in regular supplies throughout the year it may be stored in water for a few months, but should on no account be kept dry for long. Water transport is thus particularly applicable to wood intended for match manufacture. Some woods can be peeled in a fresh state, but many require boiling for several hours previous to being placed in the peeling machine.

There may possibly be scope in India for the employment of small portable machines for making splints on the Japanese plan, there being a regular cottage industry in match making in Japan. The greatest objection to this, however, is the risk of damage to the forests, and it is probable that it would not be permitted in localities where facilities for preventing such damage do not exist.

Properties of match woods.—Woods for matches should as a rule be straight and even grained, white, and soft without being brittle: they should be easily inflammable, burn with a clear flame, and when extinguished should not smoulder. There are, however, many soft woods which are not even-grained and are yet quite suitable. Matches made from coloured woods will not fetch a good price, even though their qualities otherwise may be excellent: this is due entirely to local prejudice, but the prejudice exists and has to be reckoned with. Matches are frequently dyed a bright colour, generally crimson, in order to hide any natural colour the wood may possess. Sapwood only is used for match manufacture.

Dimensions and quantity of wood used.—In the best modern peeling machines the minimum and maximum girths of logs employed are 3½ and 8 feet respectively, the best girth being 5 to 7 feet. These measurements do not include bark. The length of the logs depends on the size of the cutting machine. Ordinarily the logs should not be less than 4 feet in length; this allows of their being cut into two billets of 1 ft. 8 in. each for peeling, the rough ends of the log being trimmed off. There is no maximum limit of length required by logs brought to a match factory.

In dealing with quantities of matches, it is usual to speak of the number of gross (*i.e.*, 144) of filled match-boxes. The average quantity of timber in the round which is required to produce 100 gross of filled match-boxes is about 26 cub. feet, another 5 cub. feet being required for packing-cases to hold the filled match-boxes: this includes wastage in conversion. As a rule a match-factory of 700 gross daily capacity may be considered of fair size: many factories produce a far higher outturn, but some of the Indian factories have a smaller capacity.

Woods suitable for match manufacture.—According to European experience any species of *Populus* (poplar or aspen), *Salix* (willow), and *Alnus* (alder) is suitable for match manufacture. Coniferous wood is largely used in America and in Great Britain: some coniferous woods, however, are unsuitable owing to the large amount of resin they contain.

The most important Indian wood hitherto extensively used is the *simal* (*Bombax malabaricum*), which is one of the best match woods. The *salai* (*Boswellia serrata*) is also much used; it is often objected to on the ground that it absorbs moisture in damp weather, but an expert has recently expressed the opinion that this defect can be got rid of by boiling for 10 to 16 hours before use.

A number of Indian woods were recently subjected to practical tests for match manufacture, and the following are among the more important woods found to be suitable:—

Splints and veneers.—*Æsculus indica,* Ailanthus malabarica,* Alnus nepalensis, A. nitida, Anogeissus acuminata,*

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* Those marked with an asterisk were found to be specially good.

Anthocephalus Cadamba, Bombax insigne,* B. malabaricum,* Diospyros ehretioides,* Duabanga sonneratioides,* Ehretia lævis, Elæocarpus lanceæfolius,* Engelhardtia spicata, Erythrina suberosa, Evodia fraxinifolia,* Excæcaria Agallocha, Hymenodictyon excelsum,* Lagerstrœmia tomentosa, Lophopetalum Wightianum, Picea Morinda, Pinus excelsa,* P. Khasya, P. longifolia, Populus ciliata,* P. euphratica,* Pterospermum acerifolium,* Pyrus lanata, Salix tetrasperma, Sarcocephalus cordatus, Stephegyne diversifolia, Trewia nudiflora,* Vitex glabrata.**

Splints and inside veneers only.—*Ailanthus excelsa,* Boswellia serrata, Garuga pinnata, Gmelina arborea,* Holoptelea integrifolia, Kydia calycina, Myristica malabarica, Odina Wodier, Spondias mangifera, Swintonia Schwenckii, Symplocos theæfolia.*

Many of the above woods are of little practical importance as they do not occur in sufficient quantity : it may be noted, however, that several different woods may be used at the same factory.

The following woods have been tested and found to be only moderately suitable or quite unsuitable :—

Abies Pindrow, Averrhœa Carambola, Buchanania latifolia, Dipterocarpus alatus, Harpullia cupanioides, Pterospermum semisagittatum, Sonneratia apetala, Tetrameles nudiflora.

SECTION XIV.—WOOD USED FOR PACKING-CASES.

Wood used for packing-cases should be light, easily worked, and fairly soft, so that nails may be easily driven in without causing the wood to split, while the wood should contain no colouring matter or other substances likely to injure the contents of the box : for ordinary packing-cases the wood should also be reasonably cheap. In India there are large numbers of woods which answer this description, and yet the industry of making packing-cases, other than tea-chests and boxes for other special purposes, is not an extensive one, it being generally found more convenient to use old packing-cases of coniferous wood, usually known as deal, which have previously contained goods brought out from

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* Those marked with an asterisk were found to be specially good.

Europe, and which are either made up afresh or used as they are.

The tea-box industry is one which closely concerns India. In addition to the qualities mentioned above, wood for tea-boxes should not be liable to corrode the lead lining of the boxes; this disadvantage is possessed by many green woods, notably *Mangifera sylvatica*, *Erythrina* spp., and *Dipterocarpus* spp., and hence care should be taken to use only well seasoned wood. Deodar wood is unsuitable for tea-chests owing to the powerful odour of its essential oil: it is also too valuable. Wood for tea-boxes is sawn into ½ inch boards technically termed *shooks*; these vary in length and breadth according to the size of box required. There are many sizes of tea-boxes in use, the length usually varying from 20 to 27 inches, the breadth from 15 to 21 inches, and the depth from 13 to 20 inches in outside measurement; a smaller-sized box of 16 inches cube, inside measurement, is also sometimes used. Japan and Norway compete with India in the production of tea-boxes, numbers of coniferous tea-shooks from these countries being annually imported into India.

Among Indian woods some of the chief species used for tea-boxes are *Abies Pindrow*, *Acer Campbellii*, *A. lævigatum*, *Acrocarpus fraxinifolius*, *Albizzia stipulata*, *Alstonia scholaris*, *Anthocephalus Cadamba*, *Bombax malabaricum*, *Canarium bengalense*, *Cedrela Toona*, *Duabanga sonneratioides*, *Ficus glomerata*, *Garuga pinnata*, *Gmelina arborea*, *Mangifera indica*, *Picea Morinda*, *Pinus excelsa*, *P. longifolia*, *Sonneratia apetala*, *Sterculia villosa*, and *Tetrameles nudiflora*. Of these *Bombax malabaricum* is considered in Assam to be one of the best woods. In Dehra Dun the woods most largely used are mango and *toon*; *Bombax* is not used there as the Commissariat authorities object to this wood for boxes in their tea contracts. In Bengal and Assam *Duabanga sonneratioides* is regarded as an excellent tea-box wood. In the case of many of the white soft woods, particularly *Bombax malabaricum*, the logs should be sawn up green, or if this is impracticable they should be seasoned for a period extending up to 2 or 3 months, not longer, in water. After the shooks are sawn up they should be stacked in a dry place, with spaces between each shook, until well seasoned, the time taken for seasoning being from 2 to 5 weeks; owing to the danger of insect attacks and rot the shooks should be frequently examined, and should not be kept any longer than is absolutely necessary to season them, while in fine dry weather they should be stacked for a time on end outside to hasten seasoning.

For opium chests the planks are cut $\frac{3}{4}''$ thick, and the inside dimensions of the chests are $34\frac{3}{8}'' \times 26\frac{1}{8}'' \times 14\frac{1}{4}''$; the inside of the box is divided into a number of partitions for holding the cakes of opium. At the Patna opium factory the woods now used are mango for the boxes themselves and *Bombax malabaricum* for the inner partitions. *Sál* and *Adina cordifolia* have been used in the past, but the latter did not give satisfaction, while *sál* if not thoroughly seasoned damages the opium, in addition to which disadvantage it is now considered too expensive. *Abies Pindrow* and *Sonneratia apetala* have recently been tested and pronounced to be suitable for opium chests.

For cigar-boxes the best woods are *Cedrela Toona*, *Melia Azedarach*, and *M. composita*; *Adina cordifolia* is also used, but is not so suitable.

Boswellia serrata is used for mica boxes in Bengal, and for rough packing-cases; *Bombax insigne* is used for sugar boxes in Burma, and is worthy of more extensive use, being if anything superior to *B. malabaricum*. *Lagerstrœmia lanceolata* and *Terminalia belerica* are used for coffee boxes in S. India. Afghan grape-boxes are made of *Populus alba* and *P. nigra*.

Among the commoner Indian woods used for packing-cases and boxes in addition to the woods given above, may be mentioned *Ailanthus excelsa*, *Butea frondosa* (very rough packing-cases), *Cedrus Deodara* (used by the Ordnance Department), *Dipterocarpus alatus*, *D. tuberculatus*, *D. turbinatus*, *Erythrina* spp. *Excœcaria Agallocha*, *Ficus bengalensis*, *Hymenodictyon excelsum*, and *Odina Wodier*.

SECTION XV.—WOOD USED FOR AGRICULTURAL PURPOSES.

In India agricultural implements are more largely made of wood than is the case in countries where agriculture is in a more advanced state; in such countries iron or steel are almost entirely used for the manufacture of ploughs, harrows, and such implements. The more important wooden agricultural implements in India are ploughs, harrows, rollers, clod-crushers, forks for making hay and lifting thorny branches, water-scoops, etc.

Ploughs, harrows, rollers, and such implements are made of various hard strong woods, such as *Acacia arabica*, *A. Catechu*, *A. leucophlœa*, *Anogeissus latifolia*, *A. pendula*, *Careya arborea*, *Cassia Fistula*, *Chloroxylon Swietenia*, *Dalbergia Sissoo*, *Diospyros Melanoxylon*, *Hardwickia binata*, *Heritiera minor*, *Melanorrhœa usitata*, *Melia indica*, *Mesua ferrea*, *Ougeinia dalbergioides*, *Prosopis spicigera*, *Pterocarpus macrocarpus*, *P. Marsupium*, *P. santalinus*, *Quercus* spp., *Schleichera trijuga*, *Shorea robusta*, *Tectona grandis*, *T. Hamiltoniana*, *Xylia dolabriformis*, *Zizyphus Jujuba*, and many others, the hardest and toughest woods being used for ploughshares and harrow-teeth. Water-scoops, for scooping water from one field to another, are made of some fairly light wood which will stand alternate wetting and drying, for example *Bombax malabaricum*, *Butea frondosa*, *Terminalia belerica*, etc.; in Burma these are made of bamboo mat-work.

SECTION XVI.—WOOD USED FOR THE MANUFACTURE OF WOOD PULP.

The processes of manufacturing wood-pulp are explained on pages 281 to 287. We are concerned here with the principal kinds of wood from which pulp can be manufactured. At present the main sources of supply of pulp-wood are the coniferous forests of Europe and North America, but owing to the rapid increase in the demand for paper and the exhaustion of many of the forests which have afforded supplies hitherto, attention has of recent years been drawn to the resources of India as a pulp-producing country. Although enquiries are as yet in an initial stage, much experimental work has already been done, and it has been ascertained definitely that the following Indian woods are suitable for the manufacture of pulp: *Picea Morinda*, *Abies Pindrow*, *Pinus excelsa*, *Pinus longifolia*, *Bombax malabaricum*, *Populus ciliata*, *Sterculia villosa*, *Salix tetrasperma*, *Butea frondosa*, *Boswellia serrata*, and *Ficus bengalensis*. Further researches will no doubt reveal many other suitable woods, but many woods which might otherwise be suitable could probably never be of any economic importance owing to their scarcity. It is indeed quite probable that some of the minor products mentioned on page 207, and particularly bamboos, will, owing to their abundance, turn out to be of much greater importance as pulp-producing materials than any of the timbers of India.

Timber for wood-pulp should be soft, free from unbleachable colouring matter, perfectly sound, and with as few knots as possible : length of fibre is also an important property. The Himalayan conifers have been found to produce better pulp than the other species of Indian trees mentioned above, and the best of the conifers is the spruce (*Picea Morinda*), whose length of fibre exceeds that of any other spruce in Europe or America.

SECTION XVII.—MISCELLANEOUS USES OF WOOD.

1. *Shingles.*

Wooden shingles for roofing purposes consist of flat rectangular pieces of wood, varying in dimensions, which are nailed to the framework of the roof in such a manner that they overlap and form a watertight roof covering. In Europe and in parts of India shingles are usually made of split wood of straight grain, but the greater proportion of the shingles used throughout the Indian Empire are sawn and not split. Large numbers of sawn teak shingles are used annually in Burma, where the greater proportion of the better class of houses have shingle roofs. The sizes ordinarily in use are 15″×5″ or 15″×4″ or 12″×5″, the thickness being ½″ tapering to ¼″. Shingles of *Xylia dolabriformis* and *Hopea odorata* are also occasionally used. In Assam split shingles of *Evodia meliæfolia*, a wood which splits very easily, are made of dimensions 18″×16″×1″. In Bengal the chief woods used are *Castanopsis tribuloides*, *C. Hystrix*, *Quercus lamellosa*, *Q. fenestrata*, *Q. pachyphylla*, *Q. lanceæfolia*, *Q. lineata*, *Machilus odoratissima*, *Canarium sikkimense*. In Madras *Adina cordifolia* is employed, while in the Andamans *Pterocarpus dalbergioides* (*Padauk*) and *Lagerstrœmia hypoleuca* are used, the latter being steeped in a mixture of earth-oil and gurjan-oil. In the North-West Himalayas shingles, preferably split, are made of coniferous woods, chiefly deodar, *Pinus longifolia*, *P. excelsa*, *Abies Pindrow*, and *Picea Morinda*.

2. *Gun Stocks.*

Wood for gun-stocks should be hard, close-grained, light, not liable to split or warp, quite free from knots and other

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defects, and perfectly sound; it should be well seasoned before use. Wood impregnated with or damaged by salt water is useless, as it corrodes the steel or iron with which it comes in contact. The best wood for gun-stocks is walnut (*Juglans regia*), which requires three years to season thoroughly. For the local manufacture of stocks for sporting guns in India other woods are also used, some of which have the disadvantage of being too heavy: among the woods employed are *Adina cordifolia*, *Careya arborea*, *Cedrela Toona*, *Celtis australis*, *Chloroxylon Swietenia*, *Cordia Myxa*, *Dalbergia latifolia*, *D. Sissoo*, *Dillenia indica*, *Eriolæna Candollei*, *Gmelina arborea*, *Hopea odorata*, *Lagerstræmia Flos-Reginæ*, *Mesua ferrea*, *Mimusops littoralis*, *Morus serrata*, *Pistacia integerrima*, *Psidium Guava*, *Rhododendron arboreum*, *Taxus baccata*, *Tecoma undulata*, *Tectona grandis*, *Thespesia populnea*, and *Zizyphus Jujuba*. No Indian wood has hitherto been found quite suitable for service rifle stocks and forends. Walnut from Kashmir has been tried and found too brittle and difficult to work. Malabar teak has been found too heavy and brittle. *Stephegyne parvifolia* has been reported moderately good.

3. *Walking-Sticks.*

Walking-sticks are made from a large variety of woods, some on account of their ornamental appearance and some owing to their straightness and toughness; the latter include the sticks used for hill-climbing, which are made of *Cotoneaster bacillaris*, *Prinsepia utilis*, *Prunus Puddum*, *Pyrus Pashia*, *Cratægus Oxyacantha*, *C. crenulata*, *Parrotia Jacquemontiana*, *Celtis australis*, *Olea ferruginea*, and many other species. Large numbers of canes and bamboos are employed, the best known among the former in India being *Calamus viminalis*, *C. acanthospathus*, and *C. latifolius*; several palms also furnish good and ornamental walking-sticks, for example the so-called "Porcupine wood," which is the wood of the cocoanut palm. Among dicotyledonous woods which are not essentially hill species may be mentioned *Diospyros Ebenum*, *D. Kurzii* (Andaman "Marble-wood"), *Pterocarpus dalbergioides* (Andaman *padauk*), *Albizzia Lebbek*, *Murraya exotica*, *Dalbergia Oliveri*, *D. cultrata*, *Grewia populifolia*, *G. salvifolia*, *Hardwickia binata* and many others. Sandalwood is used for ornamental carved sticks.

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4. *Tool-Handles.*

Axe-handles are made of some hard tough straight-grained wood, among the species commonly used being *Anogeissus latifolia*, *Chloroxylon Swietenia*, *Cotoneaster bacillaris*, *Dalbergia cultrata*, *Dendrocalamus strictus*, *Grewia* spp., *Myrsine semiserrata*, *Olea ferruginea*, *Ougeinia dalbergioides*, *Tamarindus indica*, *Zizyphus Jujuba*.

For handles of chisels and similar tools some hard tough wood is required, which will stand repeated blows without splitting or becoming flattened out, for example *Acacia arabica*, *A. Catechu*, *Chloroxylon Swietenia*, *Mesua ferrea*, *Mimusops hexandra*, *Schleichera trijuga*, *Tamarindus indica*, *Xylia dolabriformis*, and many other species.

5. *Musical Instruments.*

For the sounding-boards, or bellies, of stringed instruments wood of regular structure is necessary, and it should be without any knots or other flaws which will injure the tone. The bellies of violins are made of very slowly grown coniferous wood, the sides and backs being made of maple (*Acer* spp.), In India "sitars" and similar instruments are made of teak, *Cedrela Toona*, *Juglans regia*, *Sterculia urens*, *Gmelina arborea*, *Tecoma undulata*, *Morus* spp., and other woods, while Burmese harps are made of *Pterocarpus macrocarpus*. Bamboos are also employed in the construction of certain instruments. For drums and tom-toms *Adina cordifolia*, *Albizzia stipulata*, *Artocarpus integrifolia*, *Bassia latifolia*, *Bombax malabaricum*, *Garuga pinnata*, *Gmelina arborea*, *Melia indica*, *Odina Wodier*, *Pterocarpus Marsupium*, *Sapium insigne*, *Trewia nudiflora* and others are used.

6. *Combs.*

The manufacture of wooden combs forms an important industry in several parts of India ; the wood used should be fine and even grained, of close structure, and free from defects. The chief woods employed are *Adina cordifolia*, *Ægle Marmelos*, *Buxus sempervirens*, *Calotropis gigantea*, *Capparis aphylla*, *Carissa Carandas*, *C. spinarum*, *Casearia tomentosa*, *Cratæva religiosa*, *Dalbergia latifolia*, *Diospyros Chloroxylon*, *D. Melanoxylon*, *D. tomentosa*, *Elæodendron Roxburghii*, *Gardenia* spp., *Gmelina arborea*, *Holarrhena antidysenterica*, *Holoptelea integrifolia*, *Ixora parviflora*, *Olea ferruginea*, *Pterocarpus Marsupium*, *Pyrus Pashia*, *Santalum album*, *Schrebera swietenioides*, *Stephegyne parvifolia*, *Wrightia tinctoria*, and *W. tomentosa*.

7. *Brush-backs.*

Wood for brush-backs requires to be sawn into thin boards, and should be free from any tendency to split in the process. For ordinary brushes the woods should not be too heavy, though for ornamental brush-backs heavy woods are used provided they are ornamental and otherwise suitable. The chief Indian woods used are *Adina cordifolia*, *Artocarpus integrifolia*, *Cedrus Deodara*, *Chloroxylon Swietenia*, *Dalbergia latifolia*, *D. Sissoo*, *Diospyros Ebenum*, *Holoptelea integrifolia*, *Mangifera indica*, *Millingtonia hortensis*, *Tectona grandis*, and *Terminalia Arjuna*. For ornamental brush-backs *Carallia integerrima* and *Dalbergia Oliveri* have recently been tried and pronounced suitable.

8. *Various Sporting Requisites.*

The following is a list of the chief Indian woods used for the manufacture of sporting requisites of various kinds :—

Buxus sempervirens : croquet mallets and balls.

Cedrus Deodara : poles for cricket, tennis, and badminton nets, hockey and football posts, bridge ladders, vaulting horses and frames of parallel bars.

Cocos nucifera : pegs for tent-pegging, soaked in water to soften the wood.

Dalbergia Sissoo : tennis posts, racquet presses, middle pieces for tennis, badminton, and racquet bats, bails for cricket stumps, polo mallets, croquet mallet heads and balls, Indian clubs, spring-boards and horizontal, parallel, and trapeze bars.

Fraxinus excelsior : frames of tennis racquets.

Fraxinus floribunda : cricket stumps and bails, tennis posts, tennis and racquet bat presses, polo mallets, handles of croquet mallets, horizontal, parallel, and trapeze bars and spring boards.

Grewia tiliæfolia : golf clubs.

Juglans regia : wedges or middle pieces of tennis, badminton, and racquet bats.

Morus indica: frames of tennis, badminton, and racquet bats, bends (blades) of hockey sticks, cricket stumps and bails.

Pinus longifolia: cricket, tennis, and badminton poles, hockey and football posts, bridge ladders, vaulting horses, and frames of parallel bars.

Salix alba: cricket bats. [*S. tetrasperma* has been tried, but without much success.]

Salix babylonica: the chief wood used for cricket bats in India; wood obtained chiefly from Kashmir. Used also for polo-mallets.

Zizyphus Jujuba: golf-clubs.

9. *Spinning and Weaving Machines.*

Among the chief Indian woods used for spinning and weaving machines are the following :—

Acacia Catechu: used in the Central Provinces for spokes of spinning-wheels and parts supporting the wheel, for hand-looms, and for the *muthia* or *mogri*, a dumb-bell shaped piece of wood for striking the *pinjan* or bow-shaped apparatus used in cleaning cotton.

Acacia Senegal: weavers' shuttles (Punjab and Sind).

Anogeissus latifolia: spinning wheels (Bengal).

Cotoneaster bacillaris: hand-looms and spinning wheels (Punjab).

Dalbergia Sissoo: spinning wheels.

Evodia meliæfolia: hand-looms (Assam).

Hardwickia binata: hand-looms (Madras).

Juglans regia (Walnut): hand-looms and spinning wheels (Punjab).

Olea ferruginea: cotton cleaning and spinning machines (Punjab).

Ougeinia dalbergioides: naves of spinning-wheels (Madras).

Premna pyramidata: shuttles; suitable also for bobbins, as is the wood of other species of *Premna*.

Prunus armeniaca (Apricot): hand-looms and spinning wheels (Punjab).

Schleichera trijuga: hand-looms (Travancore).

Schrebera swietenioides: beams of weavers' looms.

Shorea robusta: spinning wheels (Kols of Singhbhum).

Tectona grandis (Teak): looms (Bombay, Central Provinces and elsewhere), frames of spinning wheels (Central Provinces), and the bow-shaped apparatus known in the Central Provinces as *pinjan*, for cleaning cotton.

10. *Miscellaneous Articles.*

Tent-pegs require a hard tough wood which will not split or become flattened out when hammered, for example *Acacia arabica*, *A. Catechu*, *Anogeissus latifolia*, *Chloroxylon Swietenia*, *Ougeinia dalbergioides*, *Schleichera trijuga*, *Tamarindus indica*, *Xylia dolabriformis*, *Zizyphus Jujuba*, *Z. xylopyra*, and many others.

Saddle-trees are extensively made of *Zizyphus Jujuba*. *Anogeissus latifolia* is also used. The "Kajawa," or saddle-tree and crate combined, of the Punjabi camel, is often made of *Tamarix articulata*. For ordnance work saddle-trees of *Dalbergia latifolia* are employed.

Mathematical instruments, such as scales and foot-rules, are usually made of boxwood (*Buxus sempervirens*), while for wooden set-squares and T-squares pear-wood (*Pyrus communis*) is largely used in Europe, although many even-grained Indian woods, such as those used for comb-making, would also be suitable.

Tobacco-pipes and *hookahs* are commonly made of *Amoora cucullata* (used for hookah-stems in the Sunderbans), *Boswellia serrata* (Merwara), *Dalbergia Sissoo*, *Juglans regia*, *Mesua ferrea*, *Phyllanthus Emblica*, *Pyrus Pashia*, and bamboos. The knots cut out of dry teak logs are used for making pipes in Burma. The "briar" pipes of Europe are made of the roots of a large heath, *Erica arborea*. Certain Indian woods were recently sent to Europe for trial in the manufacture of tobacco-pipes, but none of them were found suitable, as the woods were found to sweat and crack: the woods tried were *Acacia Catechu*, *Cotoneaster microphylla* (root-wood), *Dalbergia latifolia*, *Grewia tiliæfolia* (stem and root-wood) *Ougeinia dalbergioides*, *Rhododendron arboreum* (stem and root-wood).

Toys and similar articles are usually made of wood which is easily cut and worked, and sometimes of ornamental wood. Examples of woods used are *Adina cordifolia*, *Boswellia* *serrata*, *Cedrela Toona*, *Gmelina arborea*, *Holarrhena antidysenterica*, *Morinda citrifolia*, *Pterocarpus santalinus*, *Wrightia tinctoria* and *W. tomentosa*.

SECTION XVIII.—UTILIZATION OF SAWDUST AND OTHER WASTE WOOD.

Sawdust and other waste wood, that is, small pieces cut off during conversion, may be utilized in a variety of ways. A substance known as "Xylolith" is made of sawdust cemented together into a very firm material; it is used for decorative purposes, flooring, panelling, etc. As a packing material sawdust is well known; for this purpose it should be dry and free from dust. As litter sawdust is better than leaves or pine needles, as it absorbs liquid more readily and is clean and healthy; the manure obtained from sawdust litter is also good, as the sawdust rots quickly. Sawdust may be also used for mixing with clay to form light porous bricks, or with mortar to increase its porosity. Sawdust is used in the manufacture of explosives and of dyeing material, while treated with various chemical reagents it is used for the production of cellulose, vinegar, alcohol, sugar, gum, and oxalic acid. Although sawdust burns naturally with difficulty, an apparatus has been devised for making use of it as fuel in a furnace; it is consequently a convenient fuel in sawmills equipped for burning it.

Wood-wool is the name given to fine strips of wood shaved off waste pieces or other pieces of wood by special planing machinery; these fine shavings are of various degrees of fineness, and are light, clean, and elastic, being used for packing, stuffing mattresses, surgical dressings, and many other purposes.

B.—FIREWOOD AND CHARCOAL.

SECTION I.—FIREWOOD AND CHARCOAL USED FOR HEATING AND LIGHTING PURPOSES.

Firewood plays a more important part in India than it does in many other countries where coal is more largely consumed. The value of woods as fuel is a subject which has already been dealt with on pages 51 and 52. It may be remarked generally that where wood is plentiful, and many different species are to be found, good fuel woods are almost certain to be obtainable. In arid regions, however, where tree-growth is scanty, the presence of at least one good fuel wood in quantity is a matter of importance: thus in the dry parts of the Punjab and elsewhere the wood of *Prosopis spicigera*, which is a good fuel, is largely used for mills and steamers, and is a valuable commodity in a region where tree-growth of any kind is scarce. For lighting purposes various forms of "torch-wood" are in use, for example pieces of the resinous wood from the stumps of deodar and pines, dry bamboos, etc.

Charcoal, the manufacture of which is described in Part IV, is a substance obtained by burning wood in a closed place out of contact with the air; owing to its intense, steady, and prolonged heat, and the absence of smoke, it is superior to ordinary wood for many purposes, such as ore-smelting, black-smiths' and other metal-workers' forges, cooking, machinery, etc. Specially fine charcoal for gun-powder is made from *Adhatoda Vasica*, *Butea frondosa*, *Calotropis gigantea*, *Colebrookia oppositifolia*, *Cornus macrophylla*, *Daphne oleoides*, *Hamiltonia suaveolens*, *Mimosa rubicaulis*, *Salix tetrasperma*, *Sesbania ægyptiaca*, *Trema orientalis*, and certain plants which are not of forest importance, such as stalks of cotton, *arhar* (*Cajanus indicus*) and other plants.

For lime-burning and iron-smelting charcoal from *Boswellia serrata* is used in the Central Provinces, while for iron-smelting in the North-West Himalayas *Picea Morinda*, *Abies Pindrow*, and *Pinus excelsa* are employed. Goldsmiths use charcoal made from *Rhus mysorensis*, *Cassia Fistula*, *Tectona grandis*, *Bassia latifolia*, *Acacia Catechu*, *Pinus longifolia*, *Juniperus macropoda* (Baluchistan), and other species, as well as bamboo charcoal. In the Punjab silversmiths use *Pinus longifolia* charcoal largely; it is also much used in "malting" in breweries. Some of the best charcoal woods for general purposes are the following:—*Acacia arabica*, *A. Catechu*, *A. modesta*, *Albizzia procera*, *Anogeissus latifolia*, *A. pendula*, *Bassia latifolia*, *Dalbergia Sissoo*, *Dillenia indica*, *D. pentagyna*, *Dipterocarpus tuberculatus*, *Lagerstrœmia parviflora*, *Mangifera indica*, *Melanorrhœa usitata*, *Prosopis spicigera*, *Quercus* spp., *Schleichera trijuga*, *Stereospermum suaveolens*, *Tamarix articulata*, *Terminalia Oliveri*, and *Zizyphus Jujuba*.

Probably the best charcoal wood for blacksmiths and brass-founders is *Acacia Catechu*.

In experiments carried out by Puran Singh in 1910-11 the following were ascertained to be the respective calorific powers of different samples of completely dry charcoal :—

		Calorific power (British thermal units).
1	Acacia Catechu	13,034
2	Dalbergia latifolia	12,854
3	Butea frondosa	12,415
4	Bombax malabaricum	12,398
5	Terminalia tomentosa	12,395
6	Sterculia urens	12,360
7	Terminalia belerica	12,344
8	Acacia arabica	12,296
9	Adina cordifolia	12,263
10	Tectona grandis	11,990
11	Pterocarpus Marsupium	11,887
12	Odina Wodier	11,480
13	Acacia ferruginea	11,470
14	Garuga pinnata	11,439
15	Ficus bengalensis	10,503

SECTION II.—WOODS USED FOR PRODUCTS OF DISTILLATION.

When wood is subjected to the process of dry distillation, that is, heated in a closed retort in such a way that the products of decomposition are collected, two primary products are obtained, *viz.*, *charcoal* consisting of carbon and the incombustible inorganic constituents of the wood, and *pyroligneous acid*, from which several important commercial products are obtained by further distillation or treatment with various chemicals. Among the more important products derived from pyroligneous acid are acetic acid, alcohol, chloroform, iodoform, methylene (used in making varnish), formalin, creosote, pitch and tar, besides many other substances. The manufacture of these products has not hitherto received the attention it deserves in India, but as time goes on it is hoped that a development of this industry will lead to the profitable utilization of many Indian woods which are at present of little or no value, while it should have a great bearing on the industrial progress of the country.

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The method adopted in Europe is to erect a number of comparatively small kilns with the necessary recovery plant in the neighbourhood of the forests, and to transport the crude products from these to a large central factory situated, it may be, hundreds of miles away, where the products can be worked up and refined. This saves the high cost of transporting wood over long distances.

Certain minor industries of local importance, such as the manufacture of wood-tar and wood-oil, are described in Part IV.

CHAPTER III.

Felling and Conversion of Wood.

In this chapter we shall deal with the various methods of felling and converting wood, whether for the market or for any other useful purpose. In carrying out the work of felling and conversion the primary considerations should be to follow as far as possible methods which will do least harm to the forest, and which will produce the largest quantity of such useful produce as there may be a demand for.

The subject of this chapter will be considered under the following heads :—

1. Implements used for felling and conversion.
2. Season for felling.
3. General rules of economic felling.
4. Methods of felling.
5. Extraction of stumps.
6. Rough conversion of wood.
7. Clearing of the coupe.
8. Conversion of timber.
9. Stacking of timber and firewood.

SECTION I.—IMPLEMENTS USED FOR FELLING AND CONVERSION.

1. *The Billhook.*

Billhooks are hewing implements differing greatly in form, but generally resembling a large knife or chopper. They are particularly useful for cutting brushwood, small poles and bamboos, trimming branches, preparing small billets of fuel, and similar purposes for which an ordinary axe would be too unwieldy. Various types and modifications of billhooks, as well as of similar implements used throughout India, are figured on Plate III ; these vary in weight from about 1 lb. to as much as 8 lbs., though most commonly they weigh from

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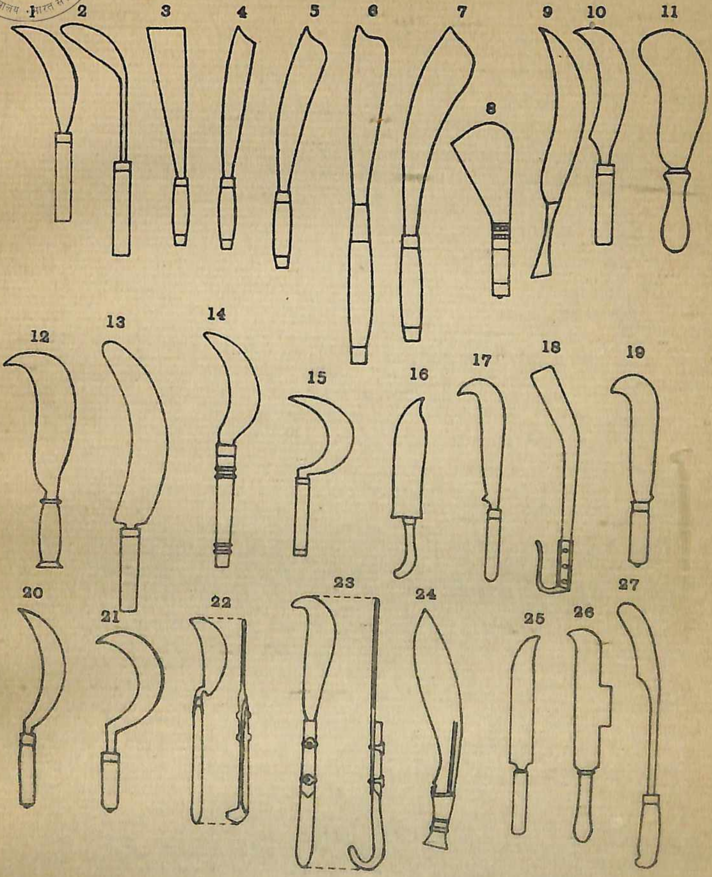
PLATE III.

TYPES OF BILLHOOKS.



1/12 natural size.

1, 2. Sunderbans dahs.
3. Assam dao.
4, 5. Burmese dahs.
6, 7. Burmese damas.
8, 9, 10, 11, 13, 20. Madras types.
12, 19. Bombay types.
14, 15, 16, 17, 18. Travancore types.
21. Central Provinces bakka.
22. Lopping billhook used by Gujars of Saharanpur, U. P.
23. Datti used in Kangra District, Punjab.
24. Nepalese kukri.
25. European type.
26. " with auxiliary cutting edge on back.
27. Ajmer dhou.

NOTE.—In all side-view figures above the cutting-edge faces the left; in Fig. 26 the principal cutting-edge faces the left and the auxiliary one the right.

[To face page 114.

2 to 4 lbs. Many jungle tribes use light axes where others use some form of billhook; to the latter class of implement belong the Nepalese *kukri*, the *da* of the Burman, the *dao* of Assam and Bengal, the *bakka* of Central India, the *koita* of Southern India, the *drahti* of the Punjab, and various other implements, many of which have curved blades like sickles.

2. *The Axe.*

The chief purposes for which axes are used are (1) felling, (2) trimming, (3) splitting, (4) grubbing: for each of these purposes a different type of axe is used, though most felling axes can, if necessary, be used for all purposes. A typical axe consists of a metal *head* and a wooden *handle*; the former is usually made of iron with a steel edge welded on, or, more seldom, entirely of steel; the handle is fitted to the axe-head through a hole (*eye*) in the latter. The portion of the axe-head in front of the eye is known as the *blade*, and that behind and on either side of the eye as the *back* of the axe.

(1) THE FELLING AXE.

The felling axe is the most important implement of the woodcutter, as it can be used not only for felling, but also for trimming, splitting, grubbing up roots, and other purposes.

Shape and weight of axe-head.—The characteristics of a good axe are that its blade should be sharp and of the proper temper, neither too soft, in which case it would bend, nor too brittle, causing it to break. The edge of the blade should be slightly curved, as a straight-edged blade is liable to have its corners broken off, while it does not penetrate into the wood so well as a blade with a rounded edge, the centre of which meets the wood first. The blade itself should taper in the form of a narrow wedge, the sides being often made slightly convex to reduce friction: where the head is furnished with a round eye, and the back of the axe has in consequence to be rather broad, a tapering blade is obtained by giving it a concave form in front of the eye (*vide* Plate IV, figs. 6, 8, 23, 27, etc.). In a good felling axe the weight of the head should be accumulated just in front of the eye; this gives it the best possible balance for delivering an effective stroke.

The weight of the axe-head depends, apart from the strength of the woodcutter who uses it, on the hardness of the

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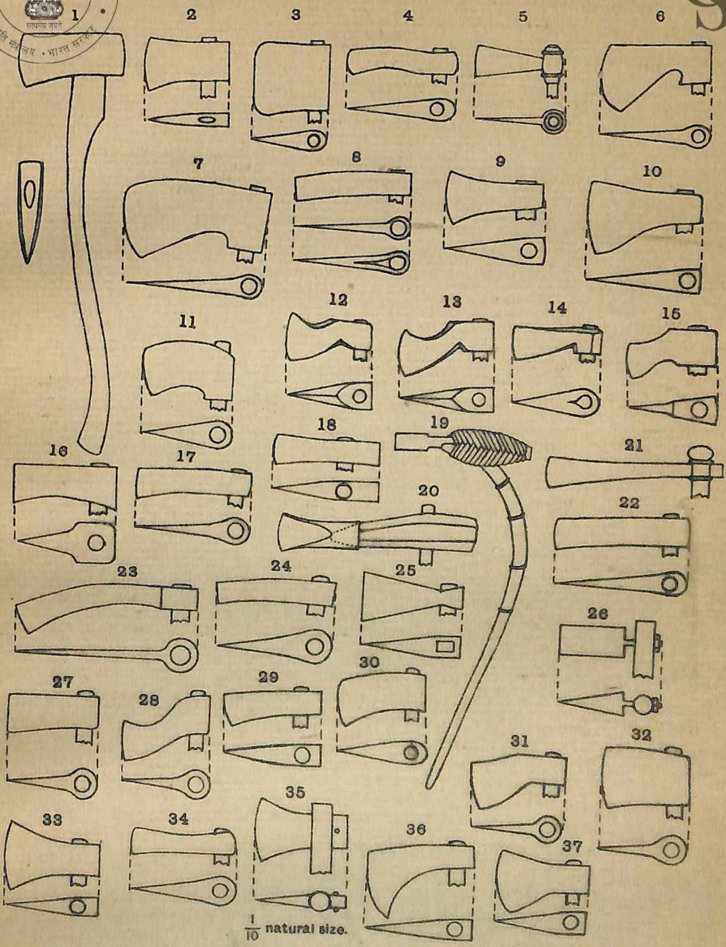
wood to be cut. For hard woods a lighter and thinner-bladed axe is required than for soft woods, because for the latter extra weight is necessary in order to crush through the yielding fibres, whereas in a hard wood the fibres cannot give so much in front of the axe, and are cut through in consequence. Moreover if an axe is driven too far into hard wood it is difficult to pull out again; this is inclined to happen when a heavy axe is used. The weight of ordinary felling axe-heads varies from 1½ to 4 lbs., but in some localities the latter weight is exceeded, while for small poles light lopping axes under 1½ lbs. may be employed. On no account should an axe be heavier than is absolutely necessary, as the heavier the axe the sooner does the woodman become fatigued, and the less will be the amount of work done.

Form of eye.—The eye may be circular or oval, or more rarely square. An oval eye is the common type in European and American axes; its great advantages are that the handle cannot slip round in the eye, and that a thinner head and therefore more evenly tapering blade can be produced: on the other hand it is apt to fly off, as the handle can be fixed in only from below, and is tightened by means of wedges driven in from above. In India the eye is almost always round; types of Indian axes with square or oval eyes are, however, shown on Plate IV, figs. 2 and 25. The advantage of a circular eye is that it is easily made and easily fitted with a handle; the handle is, however, apt to slip round in a circular eye.

The handle.—The shape of the handle varies with that of the eye. In India straight round handles are the rule, these being fitted into the usual circular eye. Where oval eyes are used the handle requires to be fitted to the shape of the eye, and is usually given a suitable shape, so that a firm grip can be obtained and a true aim delivered; such a handle is shown in Plate IV, fig. 1, which represents a useful type of American axe. To those not accustomed to use them American axes are not so effectively wielded as ordinary local axes, though they are essentially better implements in the hands of a woodman accustomed to use them than the majority of the country axes used. In America the more skilled axemen always keep both hands together at or near the end of the handle, a more effective stroke being possible in this way; unskilled axemen usually grasp the handle with the hands separated, and slide the hand nearest the

FELLING AXES.



$\frac{1}{10}$ natural size.

1.	American axe.
2, 3.	Assam types.
4, 5.	Sunderbans axes.
6.	Pahari axe, Garhwal.
7.	Delhi axe.
8.	Axe used in Bahraich, U. P.
9, 10.	N.-W Himalayan axes.
11.	Punjab axe.
12, 13, 14, 15, 16, 17.	Central Provinces types.
18.	Burmese axe, pauksein.
19.	Burmese kyettaung.
20.	Burmese kun.
21.	Malabar axe.
22, 23, 24, 25.	Madras types.
26.	Madras thari vachi.
27, 28, 29, 30, 31.	Bombay types.
32.	Axe used in Indore State.
33.	,, ,, ,, Hyderabad (Nizam's Dominions)
34, 35.	Travancore types.
36, 37.	Kashmir axes.

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head down to the other during the swing, greater accuracy in directing the blow being possible in this way. In the hands of an unskilful workman the handle of an American axe is liable to break near the eye, as it is thin at that point. A common form of axe used in America is a straight handled axe with a double-edged head, one edge being kept sharp for cutting purposes and the other used for grubbing, trimming or other rough work. The great advantage of a round straight handle is that it can be replaced without difficulty in the forest, by cutting a solid bamboo or straight stick of tough wood. Where American or other axes with specially shaped handles are used a supply of spare handles should be ready in case of breakages.

Axe-handles vary in length from slightly under 2 feet to slightly over 3 feet, a convenient average length being 2½ feet. A list of the chief woods used for axe-handles is given on page 106.

Several different types of Indian felling axes are figured on Plate IV. Among peculiar types of axes shown on this plate may be mentioned the Malabar axe (fig. 21), a somewhat similar axe used in Travancore (fig. 35), the *thari vachi* of Madras (fig. 26), and the *kun* (fig. 20) and *kyettaung* (fig. 19) of Burma.

The Malabar axe consists of a wedge-shaped head fitting into a hole in the handle, which is strengthened by two iron rings, one above and one below the hole. The axe shown in fig. 35, and used in Travancore, is somewhat similar, except that the head is held in position by a pin at the back. The *thari vachi* is of a similar type, except that the back of the head, which passes through a hole in the handle, is in the form of a bolt, a nut being screwed on behind; the head can be fixed at any angle, and the implement can be used as an adze. The Burmese *kun* is an axe with a head made of hard wood, on the front of which a steel-tipped blade fits like a cap; this blade can be turned round at any angle, adding to the effectiveness of the implement, which is wielded with great dexterity by the jungle people of Upper Burma, where it is used. The *kyettaung* ("fowl's feather") has an iron conical head about 9 or 10 inches long, the point of which is flattened out to a chisel-shaped blade with a cutting edge of about 2 inches. This iron head is fastened to a specially prepared curved handle consisting of a branch and a piece of the stem from which the branch grew; the

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stem-piece is slightly hollowed out to receive the iron head, which is firmly bound to it by strips of cane. The blade of this axe can be adjusted to any angle.

For cutting bamboos, brushwood, small coppice shoots, and for lopping and similar purposes, special light axes are used. These axes, which average about 1 lb. in weight, but may be as light as ½ lb., vary greatly in form, and among many jungle tribes take the place of billhooks, their uses being similar. Various types of these light axes are figured on Plate V, figs. 12 to 24.

(2) The Trimming Axe.

The trimming axe is used for cutting off the branches of fallen trees and for rough-squaring timber. For the former purpose a felling axe is sufficient, but for rough-squaring a specially heavy axe is necessary, those used in the North-West Himalayas being as much as 10 lbs. or more in weight. Types of heavy trimming axes are shown on Plate V, figs. 1 to 5. For rough-squaring these broad-bladed heavy axes are usually allowed to swing vertically, doing the necessary work of trimming the log by their own momentum alone: for this purpose they are furnished with specially long handles, the length of which varies from 3½ to 4½ feet.

(3) The Splitting Axe.

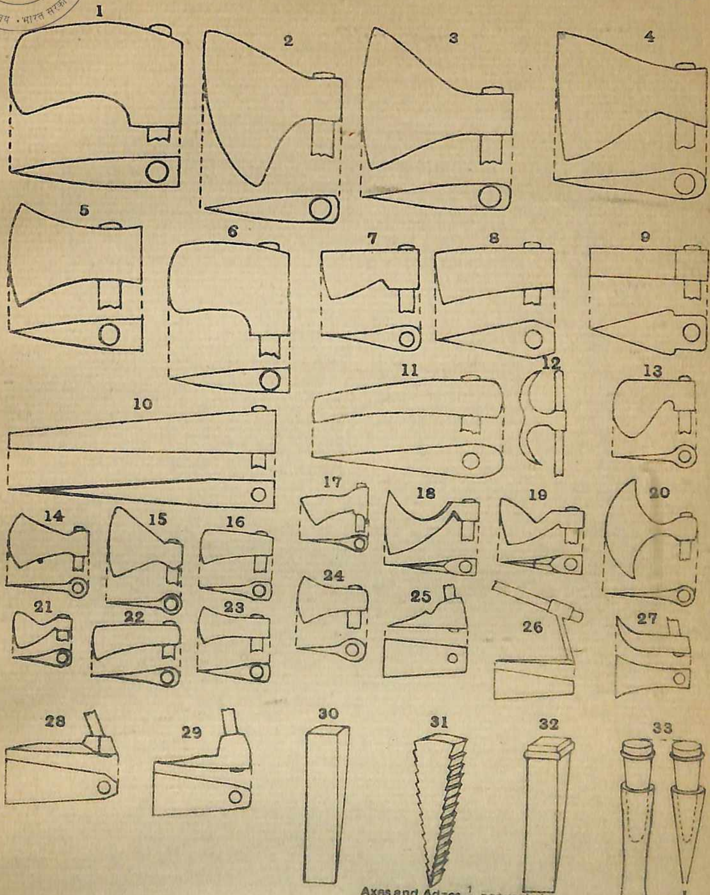
This axe is intended for splitting wood longitudinally, being used chiefly for splitting thick billets of fuel into convenient sizes. A splitting axe need not be very sharp, but should be heavy, some axes being as much as 8 lbs. in weight: the principal weight should be distributed round the eye and on the back, in order to give the axe driving power, while the blade should taper in the form of a wedge, though a slightly convex blade is also suitable. Several types of splitting axe are shown on Plate V, figs. 6 to 11.

(4) The Grubbing Axe.

The grubbing axe is intended for digging round and cutting through the roots of trees and stumps. Its characteristic feature is a long narrow slightly curved blade, the length of which is about 12 inches, the cutting edge being 2 to 4 inches broad. In actual practice any old felling axe serves the purpose of a grubbing axe.

TRIMMING, SPLITTING AND LOPPING AXES, ADZES AND WEDGES.

PLATE V.



Axes and Adzes $\frac{1}{10}$ natural size.

1. Delhi trimming axe.
2. N.-W. Himalaya trimming axe.
3. Kashmir trimming axe.
4. Travancore trimming axe.
5. Hyderabad trimming axe.
6. Delhi splitting axe.

7, 8, 9. Central Provinces splitting axe.

10. Madras splitting axe.
11. Bengal splitting axe.
12. Light axe, or balwa used in Singhbhum, Bengal.

13, 14, 15, 16. N.-W. Himalaya light lopping axes.

17. Ajmer light lopping axe

18, 19, 20, 21, 22. Central Provinces light looping axes.

23. Kashmir light lopping axe.
24. Indore light lopping axe.
25. Central Provinces adze.
26. Travancore vachu or adze.
27. Madras adze.

28, 29. Bombay adze.

30, 31. Iron wedges.

32. Wooden wedge with iron band
33. Wedge of wood with iron sheath

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3. *The Saw.*

The great advantage of the saw over the axe in felling and conversion is that it causes much less waste of wood. Saws were formerly made of iron, but all the best saws are now made of steel. The saw, which consists of a blade, toothed at one edge, is employed both for cross-cutting, that is cutting across the grain, and ripping, or cutting with the grain.

The following are some of the chief terms used in connection with the saw, for an explanation of which the reader is referred to Plate VI, fig. 1.

The *face* of the tooth (A B) is that edge of the tooth which faces the direction of cutting.

The *back* of the tooth is the opposite edge (A C).

The *space* is the distance from point to point of two adjacent teeth (A D).

The *gullet* is the entire opening between two adjacent teeth (A C D).

The *pitch* of a tooth is the angle between the face of a tooth and the line passing through the points of the teeth (angle C D A).

The *set* of the teeth is the extent to which the teeth are bent to either side of the plane of the blade.

The *gauge* is the thickness of the saw blade.

The *kerf* is the width of the cut made by the saw; it varies with the extent of the set.

Action of the saw.—The teeth of a saw act with a combined cutting and tearing action, the latter taking place more in soft woods than in hard woods, as the looser fibres of soft woods can be more readily torn asunder; for this reason more sawdust is produced in the sawing of soft woods than of hard woods.

Shape of the teeth.—The sawdust produced in sawing occupies on an average about six times the space occupied by the wood from which it is produced; thus unless the gullets are made sufficiently large there will not be sufficient room for all the sawdust to lodge between the teeth until each stroke of the saw is finished, in which case the saw will be prevented from cutting. Types of saws with enlarged gullets are shown on Plate VI, figs. 2 to 5. Some of the most effective saws are the M-tooth saws of different kinds (Plate VI, figs. 6 and 7); these are specially designed to afford the largest possible amount of gullet-space between the teeth, in comparison to the number of teeth in a given length. Another plan is to have a tooth cut off or shortened at intervals; this is an old-fashioned method not adopted in modern saws.

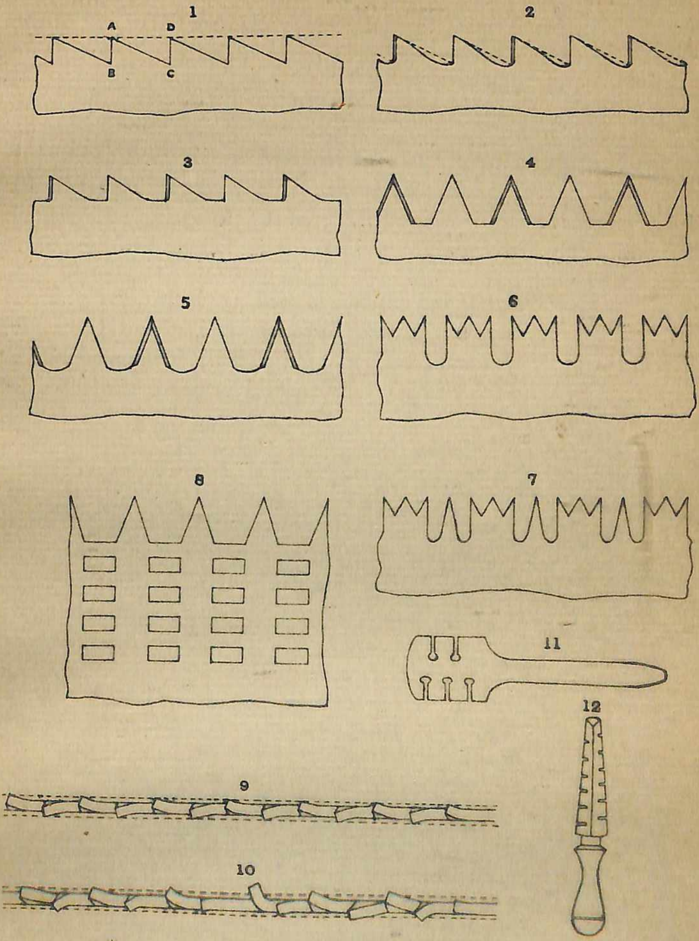
For saws which cut both ways the teeth should be symmetrical, as in Plate VI, figs. 4 and 5; for those which cut only one way the teeth are not symmetrical, the cutting face being at right angles, or nearly so, to the line joining the points of the teeth.

Sharpening saws.—To render the cutting action of the saw more efficient the faces of the teeth should be filed to a sharp edge like a knife. For saws which cut only in one direction the cutting faces of the teeth should be filed alternately on one side and on the other; this is shown on Plate VI, figs. 2 and 3. In the case of saws which cut in both directions both faces of the teeth are filed, the teeth being filed alternately on one side and on the other, as shown on Plate VI, figs. 4 and 5. The filing is done with a triangular or flat file, and care should be taken that it is evenly done on all teeth, otherwise the line of the teeth will become uneven and the saw will lose much of its cutting power, while the projecting teeth will be liable to break. To ensure the line of the teeth being kept even after repeated filing, special perforated sawblades have been devised. Fig. 8 of Plate VI shows how this is effected. Saws used in saw-mills can be sharpened rapidly by means of a special machine in which an emery wheel is brought in contact with each tooth in turn.

Setting.—By setting is understood the bending of the teeth of a saw alternately to one side and the other (*vide* Plate VI, fig. 9). If the kerf of a saw were of the same breadth as the thickness of the blade the saw would stick fast and refuse to move; hence the necessity for setting, in order to increase the kerf. A wider set is necessary for soft woods than for hard woods, while long saws require a wider set than short ones. The set should never be more than double the thickness of the blade at the base of the teeth. Forest saws are commonly set by saw-sets, such as are shown on Plate VI, figs. 11 and 12, but an ordinary saw-set of this form is very apt to make the setting uneven. If properly carried out, setting can be well done by giving the teeth a smart blow with a hammer, the correct set being obtained by placing the saw on a flat iron plate with its edge bevelled to the proper angle. Special setting implements resembling pliers are also in use. In America saws have been invented

PLATE VI.

THE SAW.



1 to 7. Types of saw-teeth.
8. Device for ensuring even filing.
9. A properly set saw.
10. A badly set saw.
11. Pit saw-set.
12. Hand saw-set.

[To face page 120.

with permanently set teeth, the thickness of the teeth being greater than that of the blade. If all the teeth are not set equally the projecting teeth are apt to get worn down quickly or to break, while the sawn surface of the wood is disfigured by scratches. A well-set saw is figured on Plate VI, fig. 9, and a badly set saw on Plate VI, fig. 10.

Forms and shapes of saws.—Saws are known as two-handed or one-handed saws according to whether they are worked by two men or by one man. The former are the most important for forest purposes, being used for felling, cross-cutting into logs, and ripping into planks, sleepers, or other classes of converted material. One-handed saws are used by carpenters, and also for cutting firewood and other small material into short pieces. A number of different types of saws are shown on Plate VII. Two-handed cross-cut saws should preferably have a convex cutting-edge, as shown in fig. 1. This facilitates sawing, in allowing for the swing of the arms, while in cross-cutting logs lying on the ground it is particularly advantageous, in that the log can be cut through without having to bring the cutting edge, as well as the workmen's hands, in contact with the ground, as is liable to be done with a straight-edged saw ; with a convex cutting edge there is also more room for the saw-dust, as the cut itself is straight while the saw is curved (*vide* fig. 2).

Other advantages of a curved saw are that there is most weight in the centre, where it is most required, and that the blade is broadest where it is most liable to wear down, there being most sharpening required in the centre. A straight saw, on the other hand, is more easy to work, and is preferable to a curved saw in the hands of unskilful workmen. For forest purposes the most suitable length for this type of cross-cut saw is 4½ to 5 feet, the breadth of blade being 8½ inches in the centre, not including the teeth, and the weight about 5½ lbs. Larger cross-cut saws of a similar type, from 5½ to 7 feet in length, are occasionally used.

A felling and logging saw worked by hand-levers has recently been tried in South India, and in one locality is said to have proved quite satisfactory.

Figs. 3 to 7 (Plate VII) give various patterns of Indian two-handed saws. The pit-saw (fig. 3), from 5½ to 7 feet in length, is much used for conversion into planks. Two common types of Indian curved saws are the Delhi saw (fig. 4) and the Maratha saw (fig. 5) ; the weight of these is ordinarily 4 to 5 lbs., though heavier saws of similar type

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are used; they are used for cross-cutting as well as for longitudinal cutting. A good pair of Delhi sawyers will saw 6 to 7 *sál* metre-gauge sleepers a day; the upper sawyer, who is the more skilled, and guides the saw, may receive as much as double the wages of the lower sawyer. Fig. 6 shows a frame-saw used for longitudinal sawing; these saws, which are of various sizes, consist of a comparatively narrow blade kept rigid by means of a wooden frame. Fig. 7 shows a cross-cut frame-saw. A common type of Indian one-hand saw is that shown in fig. 8, while fig. 9 represents the European type of one-hand saw.

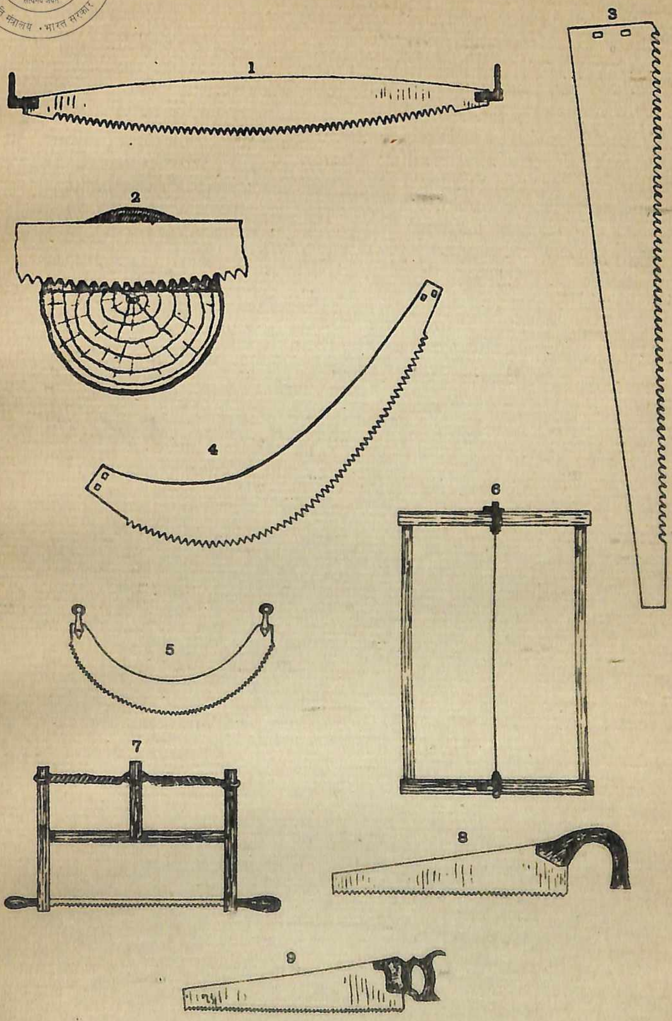
The length of a saw varies according to the purpose for which it is used. With long saws there is more risk of buckling, that is, sticking in the wood and bending, than in the case of short saws. If a saw is too short, however, it is very tiring to work with, as is a saw which is too light. The blade of a saw should be thickest at the cutting edge, tapering gradually to the back. The breadth of the blade should be sufficient to give it the necessary rigidity: the blades of frame-saws can be made considerably narrower than those of other saws.

Requisites of a good saw.—The blade should be stiff and elastic, springing back to its original shape if bent; it should be as thin and as narrow as possible provided it is sufficiently stiff. The saw should bend regularly at all points, and not more in one place than in another. The sides of the blade should be smooth and perfectly even; this can be ascertained by examining it in various lights. The blade when struck should give a clear ringing sound. To test the temper of the steel one tooth should be sharply struck on one side with a hammer; if it bends too easily the metal is too soft, while if the tooth breaks it is too brittle. The saw should be well balanced, and the handle should be firmly fixed to the blade.

4. *The Adze.*

This implement is much employed in India for trimming and squaring timber, hollowing out boats, and dressing the stools of coppice fellings. The adze in general shape somewhat resembles the axe, except that the cutting edge is at right angles to the handle instead of in the same plane with it. Adzes ordinarily vary in weight from about $1\frac{1}{4}$ to 6 lbs. or more, and the length of the handle is $1\frac{1}{2}$ to 4 feet. Types of adzes are shown on Plate V, figs. 25 to 29.

THE SAW (CONTINUED).



$\frac{1}{20}$ natural size.

1. Cross-cut saw.
2. Advantage of curve-edged Saw in producing extra space for sawdust.
3. Pit-saw.
4. Delhi saw.
5. Maratha saw.
6. Frame-saw for longitudinal cutting.
7. Frame-saw for cross-cutting.
8. Country hand-saw.
9. European hand-saw.

5. *The Wedge.*

Wedges are employed for splitting logs or fuel billets, and for assisting in the felling of trees and the longitudinal sawing of timber. Wedges are made either entirely of iron or of wood, or partly of iron and partly of wood. Some forms of wedges are figured on Plate V, figs. 30 to 33. Iron wedges have either flat sides or sides with serrate grooves to prevent the wedge from slipping out, which a smooth iron wedge is apt to do (see fig. 31). Wooden wedges are made of hard tough wood, and are sometimes strengthened by an iron band round the top (fig. 32). A serviceable form of wedge, the lower part of which is made of iron and the upper part of wood strengthened round the top by an iron ring, is shown in fig. 33. Iron wedges are driven in with a heavy wooden mallet, while wooden wedges are commonly driven in with the flat back of an axe.

6. *Implements for Directing the Fall of Trees and Extracting Stumps.*

There are various implements and devices for directing the fall of trees, particularly when they are felled by cutting through the roots, and for extracting stumps. The chief of these are the following:—

The forest devil (Plate VIII, fig. 1).—This is a powerful instrument used for extracting stumps and pulling over trees whose roots have been cut through. It consists of a strong wooden handle, to which a long chain, A, and two short chains, B and C, are attached, the ends of the short chains terminating in hooks. A separate long chain, D, is attached to the stump to be extracted or the tree to be pulled over, and the end of the long chain A is attached to a fixed object such as a standing tree or a stump. The handle is then moved to and fro, the chains B and C being hooked alternately into chain D; the whole system of chains thus becomes more and more tightened until the stump is pulled out of the ground, or the tree is pulled over, as the case may be.

The thrust-pole (Plate VIII, figs. 2 and 3).—This implement is used for pushing over trees whose roots have been partly cut through. It consists of a long wooden pole, the lower end of which rests on a serrate board fixed firmly on the ground by means of a peg: at the upper end of the pole is a spike which is pushed into the tree. The pole is pushed forward along the board by means of a couple of levers working on an iron cross-bar near the base of the pole, the tree being thus gradually pushed over in the required direction.

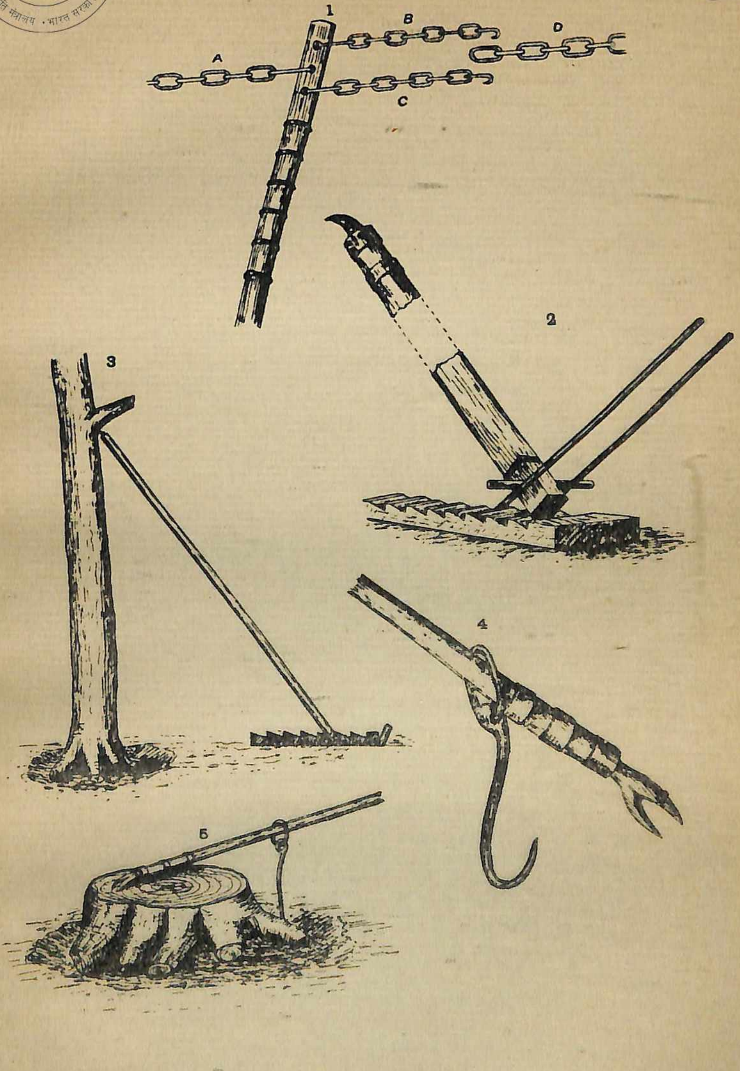
The hook-lever (Plate VIII, fig. 4).—This is a strong wooden lever with a pronged iron end and a hook attached to a ring which slides along the lever : the implement is used for extracting stumps, the method of using it being shown on Plate VIII, fig. 5. Portable windlasses and capstans may also be used for pulling down trees or extracting stumps, while for the latter purpose ordinary levers can be made use of.

SECTION II.—SEASON FOR FELLING.

In India the season for felling is so governed by climatic condition that all other factors are almost negligible ; although the available supply of labour to some extent affects the felling season, this is itself largely governed by climatic conditions. In the plains and lower hills of India the general rule is to fell as soon as the forests become dry enough to permit of work after the close of the monsoon, that is, usually from October or November onwards, the felling being completed as early as possible to enable the coupe to be cleared while the weather is dry and not too hot, for during the hottest months of the dry weather work must be done in moderation where dragging animals are employed. Felling is sometimes done during the rainy season in order to devote the whole of the open season to extraction : this, however, is not always practicable owing to the unhealthiness of the forests and their flooded state. In Burma the felling of teak is done sometimes in the rains and sometimes in the dry season, that is from October or November onwards, so that the timber may be dragged and floated during the following rains, when the slippery state of the ground facilitates dragging, and the floating-streams contain a sufficiency of water. In the Himalayas felling at the higher altitudes is done in the warm season, work being suspended during the winter owing to the depth of snow and the severity of the climate : for the winter months, therefore, the woodcutters descend to the lower valleys and work there. The labour supply affects the season of felling in that labour is often scarce during the seasons when important agricultural work is in progress. Where fire-protection is strictly enforced fellings are suspended during the fire season.

PLATE VIII.

IMPLEMENTS FOR DIRECTING THE FALL OF TREES AND EXTRACTING STUMPS.



1. Forest devil.
2, 3. Thrust-pole.
4, 5. Hook-lever.
(after Gayer).

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Apart from climate and labour supply there are other factors which influence the season of felling favourably or adversely, though as far as India is concerned some of these are of rather theoretical interest. Thus, to ensure slow seasoning timber should be cut in damp cool weather, while fuel should be cut in dry hot weather to promote rapid drying. Felling in winter, when snow is on the ground, prevents breakage of the tress in falling and also protects seedling growth from damage. For the protection of young growth the best season for felling would be the season of rest, which varies with species and locality, while during the rainy season, when young growth is succulent and tender, most damage to it would be done in felling. Coppice fellings should be carried out during the period of rest of the species concerned. From the point of view of durability in the timber the best season to fell is when there is least reserve material in the wood, that is, immediately after a new flush of leaves appears.

Section III.—General Rules of Economic Felling.

In felling trees in the forest the woodman should be guided by three chief considerations, (1) the production of the maximum amount of material with the minimum amount of waste, (2) the avoidance of damage to the felled tree and to the surrounding forest and undergrowth, (3) the nature of the locality as regards facility of export. On the basis of these three considerations certain rules for the conduct of felling operations can be laid down: these rules are as follows:—

(1) *Trees should be felled in a manner and in the direction in which they will do least damage to the forest growth.*—Sometimes the crowns or side branches of large trees are cut off before felling, to minimize the damage to the forest. Where climbers bind the tree to be felled to a neighbouring tree they should be cut at least a year before the felling, so that they may have time to die.

(2) *Trees should be felled in a manner and in the direction in which they will do least damage to themselves in falling.*—For this reason trees should

not be felled across a ravine or across felled trees, logs, or other obstructions, as they would stand a strong chance of breaking in pieces. Here again it is advantageous to lop trees before felling, as large branches exercise great leverage on the stem when the tree falls, and frequently cause the stem to split. On hilly ground felling downhill should be avoided, as the tree has furthest to fall in that direction and is most liable to become broken. The best direction to fell is uphill, the damage to the tree being least owing to the short distance through which it has to fall. In felling uphill the tree is apt to slide end-on down the slope, but it has been found by experience in the Punjab Himalayas, where deodar trees are felled uphill, being pulled over by a rope tied to the upper part of the tree, that if the tree slides down it soon stops by coming in contact with a rock or digging its nose into the ground. In felling uphill the tree is also sometimes apt to slide off the stump and kick up at its base, so that care is necessary to keep clear while the tree is falling. Where felling uphill cannot be conveniently carried out the next best direction is a horizontal one.

(3) *Trees should be felled in such a direction that the logs can be extracted most easily.*—For this reason trees should not be felled into ravines or other places from which it is difficult to extract the timber.

(4) *Trees should not be felled during a strong wind.*—This is necessary as the direction of falling cannot be guided during a strong wind.

(5) *Trees should be felled as low as possible.*—The object of this important rule is to prevent unnecessary waste.

(6) *Felling should usually begin at the top of a slope and proceed downwards.*—If felling starts from below and proceeds upwards the trees below become thinned out first, and there is afterwards more risk of trees sliding down, when the fellings have reached the upper slopes, than if the lower part of the forest were kept dense, as would be the case if fellings started from

above. Another disadvantage of commencing felling from below, especially where fuel is produced or timber is converted into scantlings, is that the stacks of fuel or scantlings would be apt to be knocked over by trees felled higher up the slope if these were to slide down, while at the same time the workmen would be exposed to danger.

(7) *Fellings should be concentrated as much as possible.*—As a general rule only as many trees should be felled at a time as can be converted and removed within the next few days. This is advisable in order to facilitate supervision and is particularly necessary where there is danger of insects attacking the felled timber, or if the timber is of a kind which is liable to rot if left lying in the forest. Logs left scattered over the forest are subject to risk from fire, theft and loss.

(8) *Valuable trees should be felled by the saw or by the saw and axe combined, and not by the axe alone.*—Felling by the axe alone causes much waste, as will be explained below.

The practice of cutting the branches or crowns off trees is commoner in Europe than in India, but its more extended use in India is much to be desired, as the amount of damage done to the surrounding trees and young growth is very much lessened. The system of cutting off the main branches before felling is carried out in the Himalayas, where large deodar trees are treated in this way. A good climber ascends the tree, lops off the main branches, and fixes a rope to the upper portion of the tree, which is then felled uphill, the axe alone being employed; the rope is steadily pulled by a number of men to guide the tree in falling in the proper direction. In Bashahr it has been found that in the case of trees averaging slightly over 9 feet in girth, the average cost of felling is one rupee, that is, about 2½ times the cost of felling without cutting off the branches and without the use of ropes; this extra cost, however, is far more than compensated by the saving of damage to the forest. As many of the larger deodar trees in the Himalayas are much branched, the felling of such trees when standing over a crop of young poles causes an immense amount of damage: in such cases every effort should be made to introduce the system of lopping before felling.

The lopping of branchy deodar trees prior to felling has of late years been introduced in the Jaunsar Himalayas with good results. Plate IX shows a deodar tree lopped for felling. In some parts of Europe skilled climbers ascend the trees by means of climbing-irons, and with an axe cut off the entire crown of the tree before it is felled.

SECTION IV.—METHODS OF FELLING.

Trees may be felled either by cutting above ground or by cutting through the roots in such a way that the tree in falling drags out the thick ends of the main roots and falls with these attached to its base. The former is the usual method of felling trees: the latter method is followed where the extraction of the stumps is desired for the purpose of clearing the ground, or where very valuable trees, such as sandalwood, are felled, the wood of the stump and the principal roots being of value.

1. *Felling above ground.*

There are three common methods of felling trees above ground, (1) with the axe alone, (2) with the saw alone, (3) with axe and saw combined. In addition to these may be added a fourth method of comparatively recent introduction, whereby trees are felled by electricity. A special steam saw for felling trees is alluded to on page 145.

(1) FELLING WITH THE AXE ALONE.

In felling a tree with axe alone a cut, A (*vide* Plate X, fig. 1) is first made on the side to which the tree is intended to fall; this cut should be made as low down the trees as possible, and should extend a little beyond the centre. A second cut, B, is then made a few inches above the level of the first cut on the opposite side of the tree; this cut should be made to meet the first cut, so that the tree becomes cut through. The fall of the tree in the proper direction can be assisted by driving billets of wood or wedges into the cut B, but if the tree naturally leans in the wrong direction or has its heaviest branches on the side opposite that to which it is required to fall, its fall should be assisted by pulling on a rope previously fixed to the upper part of the tree. A symmetrical tree requires no assistance in falling if the cutting has been properly done.

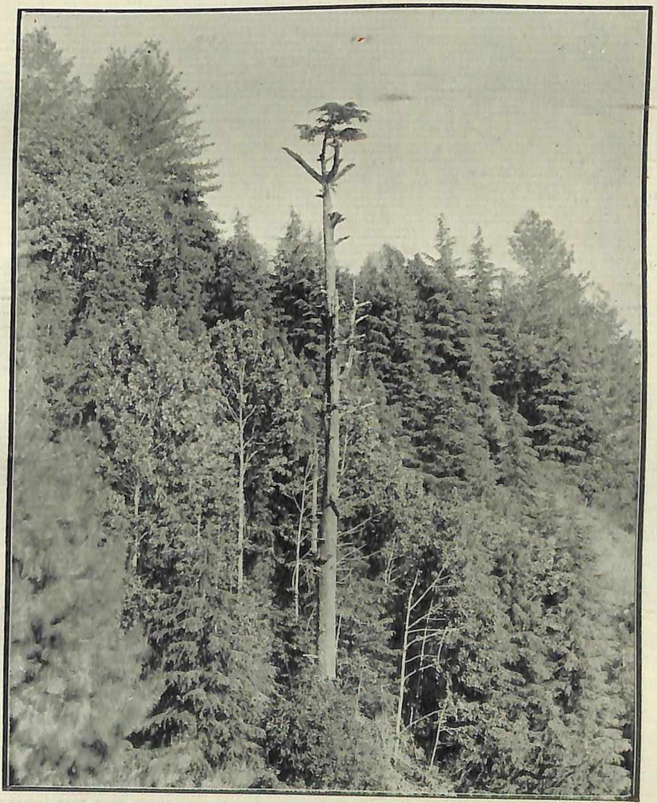

Photo.-Mechl. Dept. Thomason College, Roorkee. Photo. by Author.

LARGE BRANCHY DEODAR TREE
LOPPED PRIOR TO FELLING, JAUNSAR HIMALAYAS.

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The bases of both cuts may be either horizontal or slightly sloping, but it is essential that they should be made in such a manner that when the cutting is complete the line of contact between the bole and the stump should be perfectly horizontal and at right angles to the direction in which the tree is to fall. The two cuts can be made simultaneously by two men working on opposite sides of the tree.

Felling by the axe alone has the great disadvantage of being a most wasteful method, for not only is the wood from the cuts wasted in the form of chips, but the wood comprising the wedge-shaped end of the log has usually to be trimmed off when the timber is converted. On the other hand, the advantages of felling with the axe are first, that labour for felling with the axe is easier to obtain than sawyers' labour, second that the fall of the tree can be easily guided, and, third, that the axe is more suitable for work on rocky or difficult ground.

In felling trees for coppice the axe alone should be used or the billhook for small-sized trees, as the stump produced in sawing has a rough surface unsuitable for stools intended for coppice. Skilful workmen can carry out the trimming of the stumps and the felling of the trees in one operation, by giving an upward stroke in making the lower surface of the axe-cut, the cut being made as near the ground level as possible. In some localities the adze is used to trim the stumps after felling.

(2) FELLING WITH THE SAW ALONE.

The saw-cut begins on the side opposite to that to which the tree is intended to fall, and is continued right through the tree. Wedges are driven in behind the saw as the cutting proceeds, to prevent the saw from sticking and to guide the fall of the tree (*vide* Plate X, fig. 2). By this method there is less waste than by any other method, but the disadvantage of working with the saw alone is that the fall of the tree is difficult to guide, as the tree in falling rests on the rounded edge of the stump, and is apt to roll to one side. The fall can to some extent be guided by the use of a rope or the thrust-pole. The saw-cut may have a slightly downward slope towards the direction in which the tree is to fall.

(3) FELLING WITH AXE AND SAW COMBINED.

A cut, *A* (*vide* Plate X, fig. 3), is first made with the axe on the side to which the tree is intended to fall; this cut extends to about $\frac{1}{5}$ or $\frac{1}{4}$ of the diameter of the stem. A saw-cut, *B*, is then made on the opposite side, and is continued to meet the first cut, wedges being driven in behind the saw as advances. The base of the first cut, *A*, is sometimes made with the saw, the upper surface of the cut then being completed with the axe. This method is the most satisfactory of the three : the fall of the tree is easy to guide by reason of the axe-cut, while the waste is little more than where the saw alone is employed, owing to the small size of the axe-cut. In the Kheri forests this method is employed, but the saw-cut commences some distance above the axe-cut and slopes down to meet it ; this would seem more wasteful than where a horizontal saw-cut is made, but the advantage claimed for it is that no wedges are required, the weight of the tree aided by the axe-cut keeping the saw-cut open.

(4) FELLING BY ELECTRICITY.

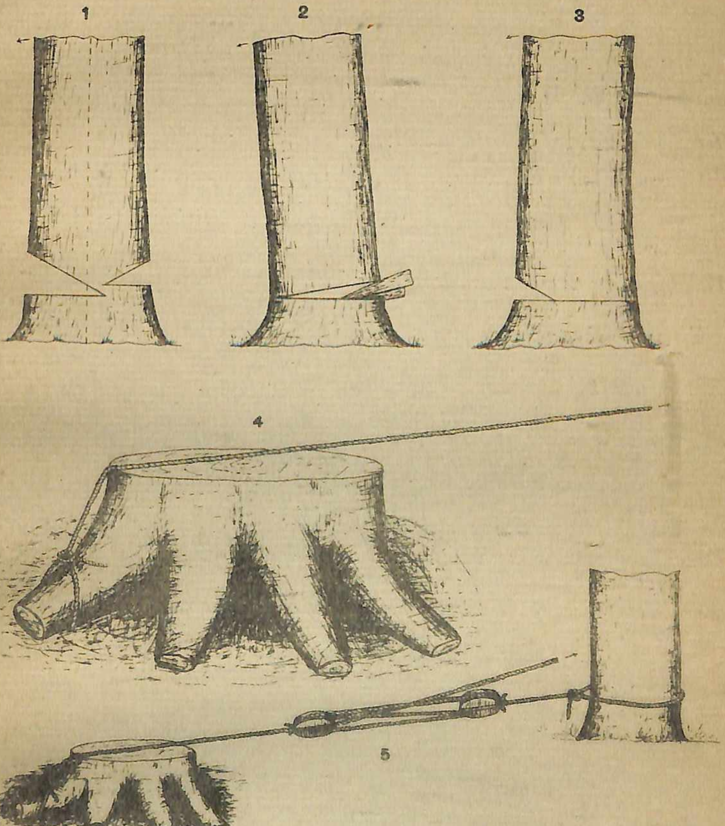
A thin metallic wire stretched in a frame with insulating handles is brought to a white heat by an electric current and used like a saw for felling trees. Another method is to fell trees by means of a rapidly revolving drill, worked by electric power ; this drill is moved backwards and forwards in a horizontal line, cutting its way into the tree. A machine for felling trees has recently been invented by Hugo Gantke of Berlin, in which a steel wire is pulled rapidly backwards and forwards round the tree, sufficient heat being produced by the friction to burn a groove through the tree : the motive power is a machine of $1\frac{1}{2}$ to 7 horse power, and the machine is said to fell a tree in half the time required for felling with a hand saw.

2. *Felling by the Roots.*

In felling by the roots the earth is first dug away so as to lay bare the principal roots, which are then cut through with an axe or small hand-saw in two places, the section between the cuts being taken out, by levers if necessary, to give access to the main roots beneath. If there is no taproot, the roots on the side away from that to which the tree is to fall are cut last, the tree being pulled over with ropes or pushed over with the thrust-pole while the last roots are being cut. Where there is a taproot it is cut last, the first cut being made on the side to which the tree is to fall, and the last cut, which should be the largest, on the opposite side ; during the final cutting of the taproot the tree should

PLATE X.

FELLING OF TREES AND EXTRACTION OF STUMPS.



1. Method of felling with axe alone.
2. ,, ,, ,, ,, saw alone.
3. ,, ,, ,, ,, axe and saw combined.
4. Method of attaching rope in pulling out stumps.
5. Extraction of stumps with the aid of ropes and pulleys (block and tackle).

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be caused to sway backwards and forwards by a number of men pulling at a rope attached to the upper part of the tree, poles being pushed further and further under the roots of the tree as it bends downwards, in such a way as to prevent it regaining its upright position.

SECTION V.—EXTRACTION OF STUMPS.

The extraction of stumps may have to be carried out, not only for the purpose of clearing land for cultivation, building sites, roads, etc., but also for purposes of utilization; thus the stumps of sandalwood trees are extracted for the sake of the large amount of oil contained in them, while those of *Acacia Catechu* are rich in cutch, and are grubbed up for cutch manufacture.

Stumps may be cut up *in situ* with axes, but this procedure is usually very slow. The chief methods of extracting stumps are (1) by the use of mechanical appliances, (2) by dragging with the aid of draught animals, (3) by blasting with powder or dynamite. Where either of the first two methods is employed the earth should first be cleared from round the base of the stump and all the principal roots cut through.

1. *Extraction by Mechanical Appliances.*

A rope or chain is attached to the stump in the manner shown in Plate X, fig. 4. The stump can then be pulled out of the ground by means of the forest devil or by a windlass or capstan. The use of the hook-lever has already been explained. Ordinary levers may also be employed; these are poles of strong tough wood with bevelled ends.

2. *Extraction by Dragging with Draught Animals.*

A rope or chain is attached to the stump as in the previous case, its other end being harnessed to a pair of oxen or an elephant; the stump is then dragged out of the ground. The dragging power can be increased by employing a system of pulleys as shown in Plate X, fig. 5, one rope being attached to the stump, another to a tree or other fixed object and the third, or dragging rope, being harnessed to the dragging animal.

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3. *Blasting with Gunpowder or Dynamite.*

To blast stumps with gunpowder a hole is bored vertically down through the stump at or near its centre with a large auger; if the centre is rotten the hole should be bored from one side, and should penetrate to the centre of the stump at its base. A charge of 1½ to 5 oz. of blasting powder, the amount varying with the nature and size of the stump, is usually sufficient. The fuse is introduced and the hole tamped with clay as in rock-blasting, the fuse being then ignited.

In blasting stumps with dynamite the hole may be bored through the stump as already described, or it may be bored through the ground in a slanting direction immediately below the stump, with as little disturbance of the soil as possible, by means of a crowbar or a 3″ earth auger. The charge of dynamite varies ordinarily from 2 to 3 oz. but a charge up to 5 oz. may be used for large firm stumps. The dynamite cartridges are introduced one at a time and firmly pressed down with a wooden tamping-rod till they fill the hole.

The detonator, attached to the fuse, is introduced into the last or primer cartridge before it is placed in the blasting hole, a hole being made in the dynamite cartridge with a small stick in order to admit the detonator. The hole should be tamped with wet earth, mud, or damp clay, the tamp being as compact as possible; the entire hole should be filled up to the top. Loose sand or gravel is of little use, as it gets blown out of the hole, and much of the force of the explosion is wasted.

Several stumps may be exploded together by electricity. The stumps are first charged with dynamite and the holes are tamped: the fuse in each stump is connected by a wire to that of the next stump until a complete circuit is obtained, when the whole group of stumps is exploded simultaneously by an electric battery situated at a safe distance from the stumps.

SECTION VI.—CLEARING THE COUPE.

The subject of transport of timber is dealt with fully under Forest Engineering, and is beyond the scope of this book. It will be convenient, however, here to make some brief mention of the chief methods employed in removing timber and other material from the felling area or coupe to the point from which it commences to be transported to

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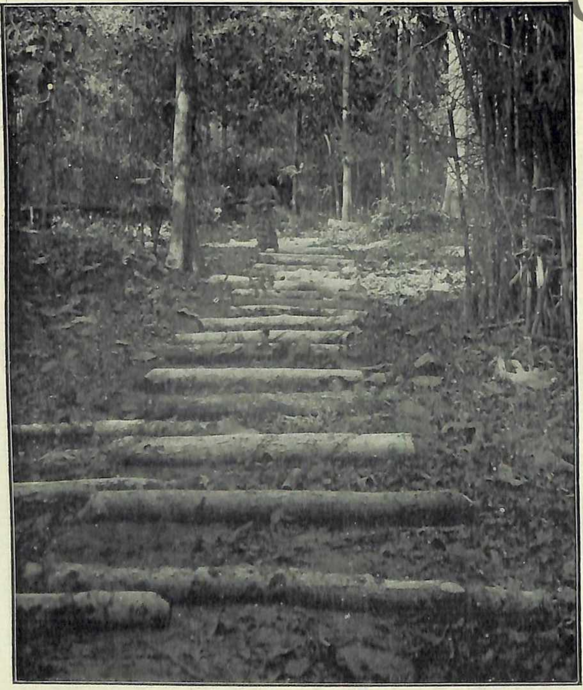
TIMBER DRAGGING-PATH, PYINMANA, UPPER BURMA. PLATE XI.



1. DRAGGING-PATH UNDER CONSTRUCTION; BILLETS LAID DOWN BUT NOT YET SUNK.

Photo.-Mechl. Dept., Thomason College, Roorkee. Photos. by Author.

2. COMPLETED DRAGGING-PATH WITH TEAK LOGS ON IT.

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some distant market. For detailed descriptions of apparatus or means of transport employed, works on Forest Engineering should be consulted.

By clearing the coupe is understood the removal of timber and other material from the felling area, whether in the round or after partial or complete conversion. The distinction between clearing the coupe and transport is not always clear, because the two operations are often identical. For example, in the Himalayas sleepers are carried off the felling area on the backs of men, and are removed by the same means often to considerable distances before they are placed in wet slides: similarly where logs are dragged from felling areas by elephants the dragging may have to continue for a mile or more until a suitable floating-stream, cart-road, railway or other line of export is reached.

There are various methods of clearing a coupe, the chief of which are carrying, removing on wheels, dragging, sliding, sledging, and rolling.

Carrying in order to clear the coupe is done chiefly by men. Where animals are employed they are intended rather for transporting material to a distance than for actually clearing the coupe. Carrying by men is expensive, and should be employed only for short distances, or where no other method is feasible. On the other hand carrying does less damage to the forest than other methods. The principal animals employed in India for carrying are mules, ponies, bullocks, and camels. In parts of the United Provinces poles and similar material are suspended on either side of a saddle and half dragged, half carried, by means of bullocks or buffaloes; this does much damage to the roads.

The employment of wheeled conveyances is a less destructive form of clearing the coupe than dragging, as the young growth is not crushed down to the same extent. Large logs may be moved by suspending them from the axle of a pair of large wheels; in this method of loading, however, the log is apt to swing from side to side, and the chains are liable to break. Wheels cannot be employed on very rough broken ground or hilly country, so that their use is somewhat restricted; they are also less suitable for transporting logs or other material over short distances than dragging, because of the time taken in loading and unloading.

Dragging is done by men or by draught animals. It may be facilitated in either case by placing round billets under the logs to act as rollers, these being taken up from behind and placed in front of the log as it proceeds. A dragging-path, particularly on soft ground, can be greatly improved by placing billets of wood about 4″ to 6″ in diameter some 3 to 4 feet apart across the path, after the manner of sleepers, longer billets being placed at the curves; these billets, over which the logs slide easily, are half sunk in the ground, and may if necessary be kept in position by wooden pegs driven into the ground. A dragging-path of this kind is figured in Plate XI. Dragging can be employed in more hilly and broken country than carting, but is not so suitable for transporting timber over long distances because of the strain on the dragging animals. Dragging should not be allowed on permanent roads, as it cuts up the road-surface; in the forest it is advisable to have temporary dragging-paths over which many logs are dragged, so that unnecessary damage to the forest may be avoided.

There are various methods of attaching the dragging-chain to the log. One method is to employ a pair of grappling hooks (Plate XII, figs. 1 and 2), which are hooked into two small niches cut one on either side of the log a few inches from one end of it; when the pull is exerted the chain tightens, keeping the hooks firmly embedded in the niches. In spite of its advantages, this method is not always satisfactory, for unless a steady pull is maintained, which is not the rule with elephant haulage, the hooks are liable frequently to become detached. Another method is to drive an iron spike, to which a ring is attached, firmly into the end of the log, the dragging rope or chain being fastened to the rope (*vide* Plate XII, fig. 3). A common method of fixing the dragging chain is to cut a hole through the corner of the log a few inches from its thick end. The end of the log is apt to dig itself into the ground during dragging, and for this reason it is necessary to adopt some device for preventing this. A somewhat wasteful method is to "snout" the thick end of the log, that is, to trim it into a rounded form to prevent it from catching in the ground (*vide* Plate XII, fig. 4). This plan is not so common now as it was formerly, owing to its wastefulness; it is generally found sufficient to round off the corner of the log which meets the ground during dragging, as in Plate XII, fig. 6. The correct method of logging timber in order to minimize the waste caused by the cutting of the drag-hole is explained on page 138 and shown on Plate XII, fig. 7. Various forms of short sledges, boards, or pairs of small wheels placed under

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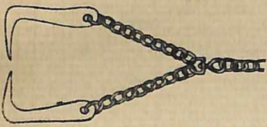
PLATE XII.

MOVING AND ROUGH CONVERSION OF TIMBER.

1



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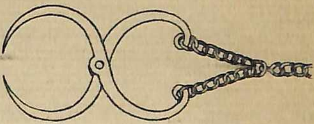

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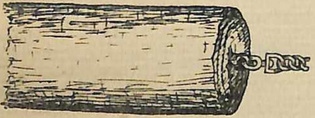

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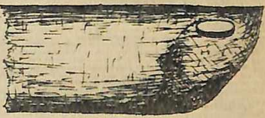

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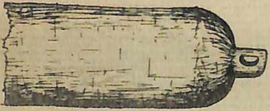

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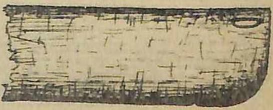

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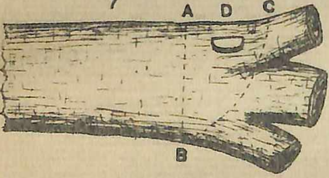

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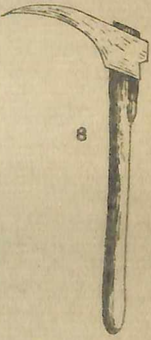

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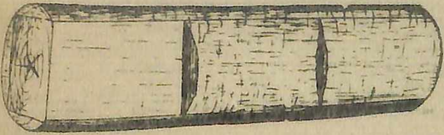

1. & 2. Hooks for attaching dragging-chain to logs.
3. Iron spike for dragging purposes.
4. A "snouted" log with drag-hole : wasteful method.
5. Another wasteful method of preparing log for dragging.
6. Correct method of trimming log for dragging with drag-hole.
7. Logging to prevent waste in cutting drag-hole. A B—incorrect cut. B C-correct cut. D—drag-hole.
8. German krempe, or lever for moving logs.
9. Method of rough-squaring logs.

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the front end of the log during dragging, are also employed to prevent it from digging into the ground. Another form of drag-hole sometimes employed is cut in or near the centre of the butt as shown in Plate XII, fig. 5, but this method is, like "snouting," very wasteful, as the end of the log has to be trimmed to a more or less conical shape.

Drag-holes may be dispensed with, especially for small logs, the dragging-chain being merely passed round the log near the thick end and tightened; two or three small logs may be fastened and dragged together in this way. If logs are rough-squared on the felling site an unsquared piece should be left at one end, so that the dragging-chain may be passed round the rough end, which keeps the chain from slipping off.

The most powerful timber-dragging animal is the elephant. In some parts of the country, particularly in Burma and the Andamans, the bulk of the timber supply, as far as the more valuable classes of timber are concerned, depends on the available supply of elephants for dragging purposes. Elephants are also employed for dragging timber in parts of Bombay and Madras. A large proportion of the large-sized teak timber of Burma is dragged from the coupe to the floating-streams by elephants, two, three, or more animals being harnessed to a single log if its weight is too much for one animal. The best dragging gear consists of a breast-band, to which the dragging chains are attached, and a small wooden saddle, padded underneath, over which passes the rope which keeps the breast-band and dragging-chains in position. Plate XIII gives an idea of timber working by elephants, as carried out in Burma. The amount of work an elephant can do *per diem* varies greatly according to circumstances: a good average day's work for one elephant is to drag a ton of timber 1 to 1½ miles where the country is not too difficult.

After elephants, the animals next in importance for dragging purposes are buffaloes, while oxen are employed for medium or smaller sized logs. The animals are usually yoked together in pairs, the dragging-chain being attached to the yoke.

By the construction of dragging-paths laid with billets of wood, as described above, it has been found possible to drag large teak logs of as much as 4 tons with the aid of teams of 2 to 4 pairs of buffaloes.

In Burma dragging by elephants and buffaloes is usually done in the rains and the cold season, as little as possible being left till the hot weather. Dragging is easiest in the rains, owing to the slippery nature of the ground; it has even been found from actual trial that dragging in the rainy season may be as much as three times as easy as in the dry season on the same ground.

Where the dragging of logs has to be done up steep slopes the block and tackle arrangement mentioned on page 131 (*vide* Plate X, fig. 5) can be applied with success.

Sliding is employed on hilly ground where the gradient is too steep for dragging, the logs being allowed to slide end-on down the hill-sides by their own weight. The speed of a log can if necessary be controlled by attaching to one end of it a long rope which is passed once or twice round the trunk of a tree and held by a workman, who can regulate the speed of the log by tightening or slackening the rope. The tree round which the rope is passed should either be one about to be felled or one of little or no value, as the bark is almost certain to be torn off by the friction of the rope. Logs should be slid as much as possible down the same track, to avoid unnecessary damage to the young growth on the ground. It is often necessary to prepare an "earth slide" which may be merely a natural hollow running down the mountain side, or an artificially prepared depression. In constructing an earth slide a certain amount of preparation is necessary in the way of removing rocks and other obstructions from the sliding path. In gradient an earth slide may vary within wide margins, usually between 20° and 60°, but on a gradient of more than 25° it is impossible to prevent the logs from sliding down without control unless walls known as check-walls are constructed across the path at intervals. With low gradients the sliding of the logs is assisted by means of levers, but care is taken not to allow the logs to slide down without control. Earth slides in the Himalayas are usually straight, but gentle curves, if they do not occur at too frequent intervals, are rather an advantage than otherwise. Posts or walls are erected only at points where the logs are liable to leave the slides. In Europe the sides of earth slides are protected by poles; fairly sharp curves can be constructed on such slides. Care should be taken to remove the logs when they reach the termination of the slide, so that others coming down later may not get broken or split by collision with timber lying on the ground.

TIMBER WORKING BY ELEPHANTS. RUBY MINES DIVISION, UPPER BURMA

PLATE XIII.

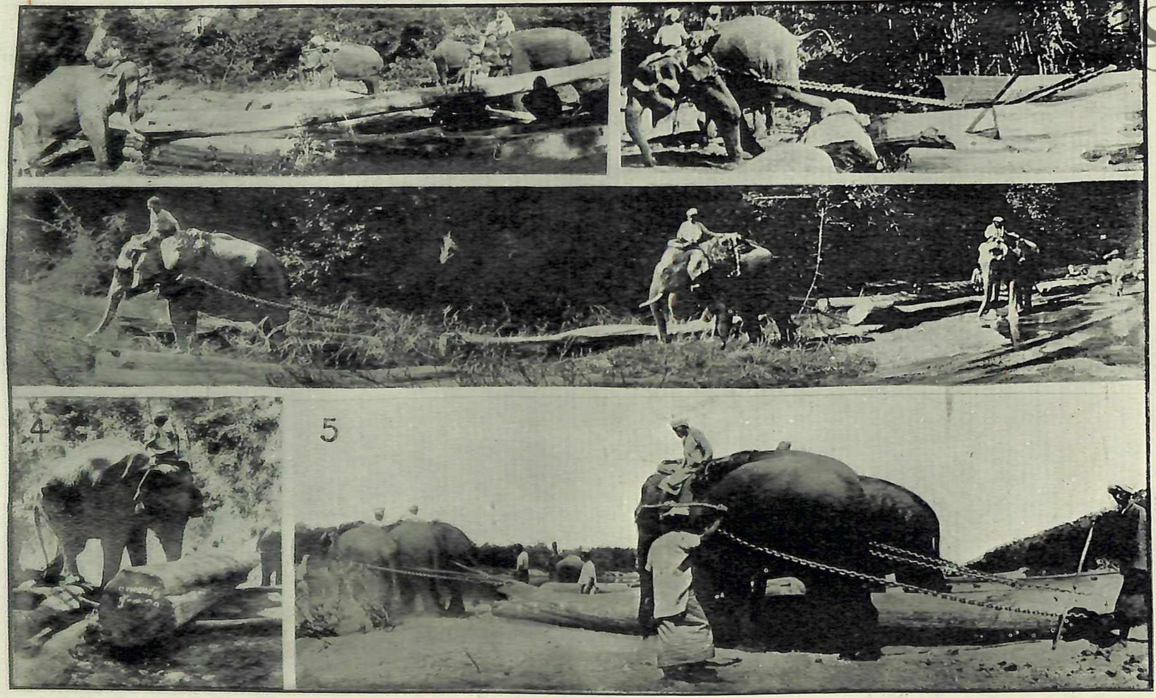


Photo.-Mechl. Dept., Thomason College, Roorkee.

Photos. by Arthur Boyd.

1 PUSHING. 2. 3 & 5. DRAGGING. 4. ROLLING.

[To face page 136.

Sledging is a useful method of clearing the coupe, as sledges can be employed both for timber and for fuel. There are many forms of sledge, the essential feature of all being a pair of parallel runners made of hard wood; these take the place of the wheels of a cart. Sledging is most suitable for winter when there is snow on the ground. Bullock-sledges are sometimes used in Saugor, Central Provinces, chiefly for the export of small material such as firewood.

Rolling can be carried out only on ground fairly free from trees, rocks, and other serious obstructions. It can be done by men with the aid of ordinary levers, the hook-lever, or a useful German form of lever known as the *krempe* (Plate XII, fig. 8).

Elephants can be employed for rolling timber; this they do by pushing the logs with the tusks or the base of the trunk. In some of the Himalayan forests special rolling roads are constructed for the extraction of deodar logs. Rolling should never be employed on ground covered with reproduction, or on steep slopes in places where there are many people about, as the rolling of logs down steep hill-sides uncontrolled is highly dangerous.

A rolling-road is a specially constructed road for rolling logs down a gentle incline. The maximum and mean gradients should not exceed 10° and 3°, respectively, while sharp curves should be avoided as much as possible; hence the construction of such roads is expensive where many obstacles are met with. Two parallel lines of poles are laid, like rails, along the rolling-road, these being partly embedded in the ground to keep them firm. The logs are rolled in batches of 10 to 20, the only implements used being levers about 6 feet long. The foremost log of the batch is kept from rolling forward by stones and wood wedged under it in front. More stones and wedges are then placed about 30 feet in front, and the original stones and wedges are knocked out from under the log; the logs are then rolled forward with levers, and come to a stop where the stones and wedges have been placed. This operation is repeated constantly so that the logs may not get out of control. In exceptional cases a stream-bed may be transformed into a rolling-road by removing large stones and laying poles along its bed.

The system of rolling logs is not unattended by accidents. Men have to keep in front of the rolling logs to stop them or guide them with levers, a work which is somewhat risky. Rolling-roads are most in use in the Punjab Himalayas.

Anything more elaborate in the way of export works than the devices described above must come under the head of transport of timber and are beyond the scope of this work.

SECTION VII.—LOGGING AND CONVERSION OF TIMBER.

1. *General.*

Timber is ordinarily logged at the felling site, and may be converted either in the forest or after extraction, while the conversion may be carried out either by hand or in sawmills.

The actual classes of converted material to be produced must depend on the demands of the market, but one general maxim should always be followed, namely, that the method of conversion should involve as little waste as possible. One of the most fundamental rules of economic conversion, accordingly, is that the axe should not be employed where the cutting can be done by means of the saw, because the waste produced in sawing is much less than that produced in cutting with the axe. This rule is, unfortunately, often disregarded in India, but every endeavour should be made to promote the use of the saw in preference to that of the axe.

2. *Logging.*

When a tree is felled its branches and excrescences are trimmed off and the bole is sawn into logs, the size of which depends on the demands of the market and the purpose for which the timber is required. Where only fuel is saleable the bole is cut and split up for fuel. Where fuel is not saleable the branch-wood is usually left lying as waste in the forest, except such as can be employed for poles, posts, or other marketable material. Where, however, timber and fuel are both saleable, all material not required for timber is cut up into suitable lengths, sorted into different classes, and either temporarily stacked in the forest or at once removed. If insect attacks are feared the timber should either be barked at once or immediately removed.

Where logs are to be "snouted" or otherwise trimmed for dragging purposes, or where drag-holes are to be cut, care should be taken to make the top log include the base of one or more branches if possible, and not to log the tree immediately below where it branches. In this way the drag-hole can be cut in the base of a branch and not in the log itself; this is explained in Plate XII, fig. 7. Similarly if a tree is crooked the greatest length of undamaged straight timber is obtained by logging a few inches into the bend, and cutting the drag-hole in the bend.

Ordinarily timber is completely logged at the felling-site, but sometimes it may be convenient to drag longer logs than it is possible to float, in which case logging is commenced at the felling site, long logs being dragged to the floating stream and there cut into shorter lengths before floating.

3. *Rough Conversion.*

By rough conversion we mean such operations as rough squaring logs and trimming off sapwood, as well as partial fashioning as in the case of half-made naves, spokes and felloes of wheels, cask-staves, and other articles which are often partially fashioned in the forest before extraction. We may also include under rough conversion the cutting and splitting of fuel. Rough conversion is usually carried out in the forest, frequently at the felling-site itself, the chief object being to cheapen the cost of extraction by reducing the bulk or weight of the material to be extracted.

The different classes of timber in the rough have already been given on page 64; the demand for each of these classes should be taken into account during the rough conversion and sorting of the timber.

The rough squaring of timber facilitates extraction where this is done by carting or carrying. The corners of the square should first be marked with a string blackened with powdered charcoal and water or oil; the string is stretched tight along the log by two men, one at each end of the log, while another man pulls it away from the log in the centre and then releases it so that it strikes the log and leaves a black line. The squares are also marked off on the ends of the log. Rough squaring is usually done with a trimming-axe or adze. If the log is a long one the squaring should be done in sections, a number of cross-cuts being made at convenient intervals to guide in the squaring (*vide* Plate XII, fig. 9).

Fuel may be converted and classified into four main classes, (1) split billets, that is, the larger pieces which have to be split to convenient size, (2) round billets, that is, pieces which are not too large to use in the round, (3) root-wood and stump-wood, that is, pieces cut to convenient size from roots and stumps, and (4) faggot-wood, which includes small-sized branch-wood and other small material, which is tied up into bundles and is sold chiefly for domestic use.

An elaborate system of rough conversion is applied in the case of sandalwood in Madras. The trees are felled either by the roots or at the ground level, the roots and stump in the latter case being afterwards grubbed up. The stem and roots are cut into billets of convenient size for transport, great care being taken in this, as the value of the billets is much enhanced by freedom from bends or knots. The sapwood is trimmed off with an axe or adze, all except a thickness of about $\frac{1}{8}$ of an inch, which is left on to protect the heartwood. All pieces are so treated, whether stem, branches, or roots, except branches with a section of heartwood less than the size of a rupee, and small roots. Felling and billeting is done entirely by the saw, the use of the axe being rightly forbidden. To prevent theft the sawn sections of each piece are numbered and the grain of the wood on all corresponding sections is compared on arrival at the depôt.

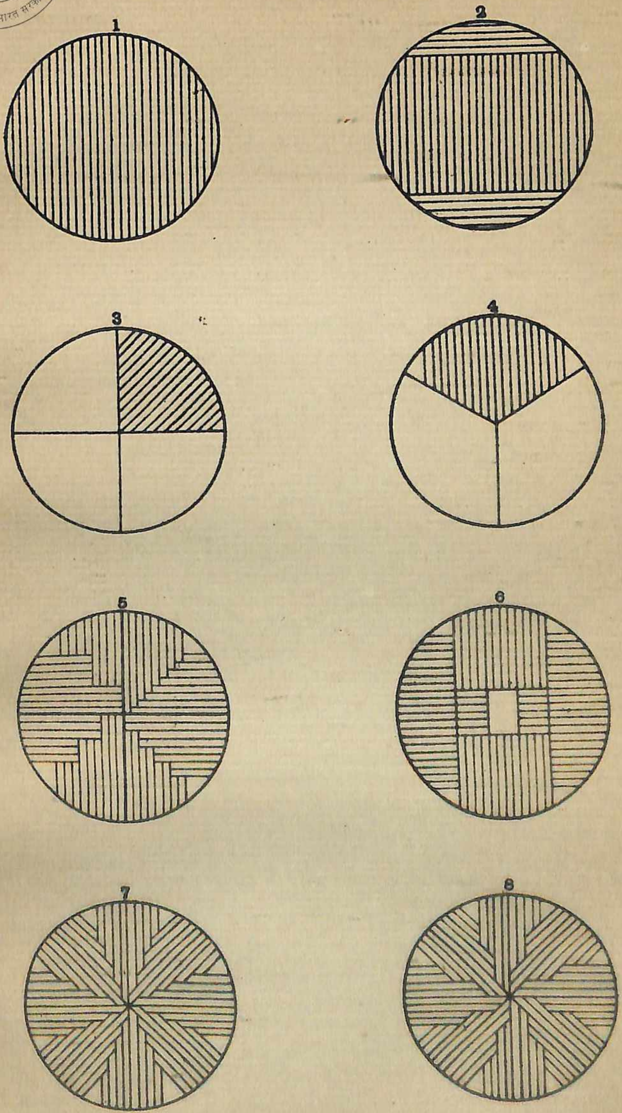
Among the many different forms of rough conversion practised in India, one of the most important is perhaps the rough fashioning of cart-wheel naves, spokes and felloes, which are cut to approximate dimensions in the forest, to be finished off subsequently after extraction.

4. *Sawing of Scantlings.*

When it is intended to saw a log up into planks or scantlings the usual method is to mark out the sections of the converted material on the ends of the log, and to mark longitudinal guiding lines along its surface, after which the sawing proceeds. The heart of the log is often slightly unsound, so that it may have to be avoided for sawn material. For ordinary purposes boards are shown in the manner shown in Plate XIV, figs. 1 and 2: it will be seen from the diagrams that the boards so produced are cut largely on a tangential section. Now, as radially-sawn boards are not only stronger and less liable to warp, but are in many cases also handsomer in grain than tangentially-sawn boards, it is preferable, except for ordinary rough use, to obtain as many radial boards as possible. There are various ways of sawing up logs to effect this

PLATE XIV.

CONVERSION OF TIMBER.



1, 2. Ordinary methods of sawing.
3, 4, 5, 6, 7, 8. Methods of sawing with the silver grain.

[To face page 140.

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object, the chief of which are shown in Plate XIV, figs. 3 to 8. There is one disadvantage, however, in sawing according to intricate patterns, and that is, that such patterns are more difficult and tedious to mark out than the simple patterns shown in figs. 1 and 2, which for mill sawing need not even be marked out at all : hence except for the better class of boards the simpler patterns are sufficient.

When scantlings of different sizes are in demand the classes which fetch the highest price per cubic foot should be marked out first, the remainder of the space being marked out with less valuable sizes of scantlings. Conversion into railway sleepers is one of the most wasteful forms of conversion, so that if there is much demand for miscellaneous scantlings it usually pays better not to convert into sleepers : this is particularly the case with broad-gauge sleepers, where the wastage, even in sound logs, may amount to half the volume of the log, or more.

5. *Conversion by Hand.*

Conversion by hand may be carried out either in the forest or after the removal of the timber to a more central place. The method of rough-squaring with the axe has already been described; the subsequent conversion into scantlings and other ordinary classes of materials should be done with the saw. There are various methods of placing the logs in position for sawing, these varying according to the type of saw used and to local custom.

Where long pit-saws are employed for longitudinal sawing, the logs are either placed on the ground level over a pit dug in the ground, or raised on a skeleton platform of poles at a height of 6 to 8 feet from the ground : in either case one sawyer stands on the log and the other stands below it. Where a raised platform is employed the log is pulled by ropes, or pushed by levers up an incline formed by two or three poles placed at a gentle slope against the side of the platform. Where a pit is employed the log is merely rolled over the pit so as to rest on poles placed there to receive it. With short saws it is sufficient to raise one end of the log off the ground, by resting it on another log or on a trestle. Where the log or square to be sawn is in such an inclined position as to render a firm foothold for the upper sawyer impossible, a rough form of ladder, consisting of saw-like steps cut out of a single piece of wood, is placed against the inclined surface of the log to be sawn. Plate XV, fig. 1, shows the method of sawing sleepers by this means in the North-West Himalayas, a frame-saw being used. Plate XV, fig. 2, represents a Delhi sawyer's trestle, for sawing short logs.

6. *Conversion in Sawmills.*

(1) GENERAL.

So far as the Indian Empire is concerned, sawmills are more extensively used in Burma than elsewhere, this province containing a far greater number than all the other provinces combined.

As the establishment of a sawmill means the sinking of much capital, it should never be undertaken until the local conditions have been thoroughly studied. It may be said in general that the establishment of a sawmill is advisable under the following conditions :—

(1) that there is a plentiful and regular supply of timber in the round, in order to keep the mill regularly at work,

(2) that the timber can be brought to the mill in the round at a reasonable cost,

(3) that there exists at least one good line of export for the converted material from the mill,

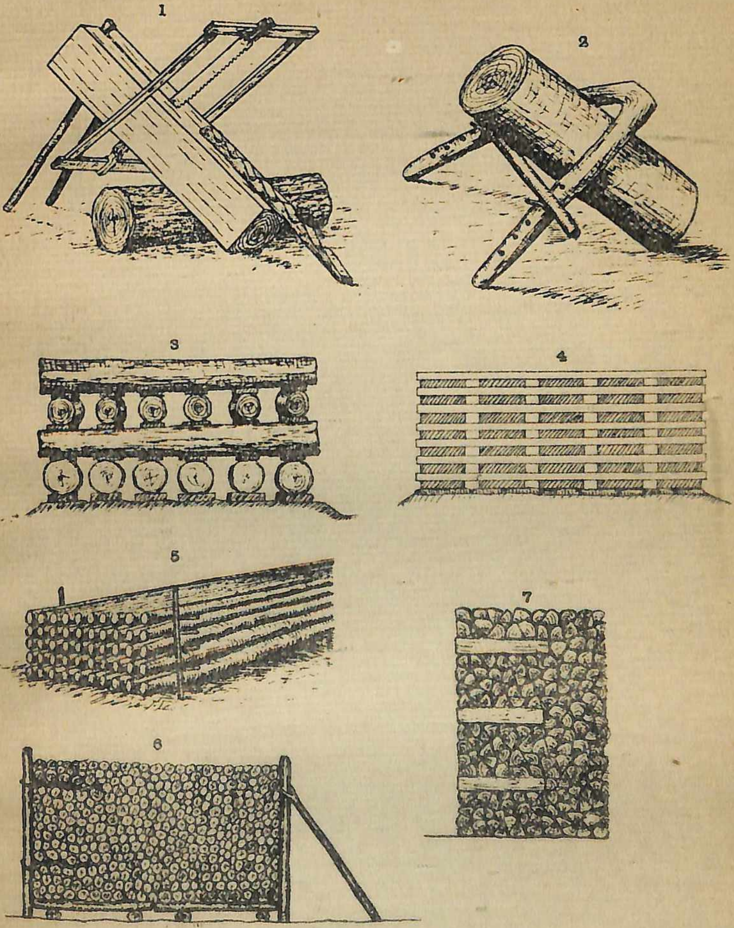
(4) that there is a sufficient demand for all the material that can be converted at the mill,

(5) that the working of the mill is likely to realise a reasonable profit : this will depend a good deal on the state of the timber market and the cost of labour.

On the other hand a sawmill should not be established (1) where the timber is not available in sufficient quantity to keep the mill regularly employed, (2) where the timber available is largely hollow or unsound, so that the proportion of waste is very large, (3) where the timber cannot be extracted in the round except at a very high cost; in such a case conversion in the forest would usually be more profitable, (4) where there are no good lines of export from which converted material can be exported from the mill, (5) where there is no steady demand for converted material, (6) where there is a plentiful supply of cheap labour for hand conversion in the forest ; in this case it is usually more profitable to convert it in the forest by hand sawing.

PLATE XV.

CONVERSION AND STACKING OF WOOD



1. Sawing of sleepers with frame-saw.
2. Delhi sawyer's trestle.
3. Stacking of logs.
4. ,, of scantlings.
5. ,, of poles.
6, 7. Methods of stacking fuel.

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Sawmills in India are worked by steam-power. In Europe water-power is sometimes employed, but it is not usually adaptable in India owing to the fact that the perennial supply of water is not sufficiently large or steady in those parts of the country where sawmills are chiefly in operation; besides this the abundance of wood fuel from waste pieces obtained during the conversion of timber renders steam-power comparatively cheap.

According to their situation, sawmills may be classed into forest sawmills and sawmills situated at some central place away from the forest. The latter are permanent and are usually larger and more completely equipped than the former. Forest sawmills are commonly of a smaller and more primitive type; they are situated within or in close proximity to the forest, and may be either permanent or temporary, the latter being portable, and usually on wheels, so that they may be shifted from place to place. Where conversion has to be carried out in the forest and labour for hand-sawing is expensive, portable forest sawmills are specially suitable. They have recently been introduced into Burma, but there they are as yet in an experimental stage.

(2) KINDS OF SAWMILLS.

Every sawmill consists of three essential parts, (1) the saw and frame, (2) the mechanism which feeds the logs into the saw, and (3) the machinery which drives the mill. As regards (2), the mechanism consists either of a movable carriage or bench on which the log is placed and moved towards the saw, or a "roller-feed" consisting of a series of revolving rollers which move the log along towards the saw: the latter is suitable for even-grained soft woods, such as conifers, which are easily sawn, and not for hard or uneven-grained woods. The saw itself may be one of three principal types, (*a*) the reciprocating frame-saw, (*b*) the circular saw, and (*c*) the band-saw.

The *reciprocating frame-saw* is nothing more or less than a mechanical adaptation of the hand frame-saw. It consists of a frame, containing one or more saw blades; the frame moves vertically up and down, sawing with the reciprocating motion employed in all hand-sawing. This form of saw is the most primitive of the three forms of machine-saws, but is still largely employed in Europe. The number of blades which can be fixed in the frame at one time depends on the horse-power of the mill and the kind of timber to be sawn ; where the power is sufficient, as many as 20 parallel blades may be fixed at a time, their distance apart being adjustable at will, so that the thickness of the boards sawn may be regulated. These machine frame-saws containing a number of blades are termed multiple saws. The advantage of the frame-saw as compared with the circular-saws is that it requires less power to drive and is less wasteful ; but on the other hand it turns out its work much more slowly.

The *circular-saw* consists of a flat circular steel blade with a continuous row of teeth round the margin ; it works by revolving rapidly in one direction, like a wheel, round a horizontal axis. Where waste of wood is not of vital importance, and motive-power is cheap, the circular-saw is the best machine-saw for general purposes, as it turns out its work with great rapidity. One of the chief disadvantages of circular-saws is that they cannot saw timber of very large girth. Although circular-saws are sometimes made up to 7 or 8 feet in diameter, they are not to be recommended for general use above 6 feet : this would make the maximum diameter of logs which could be sawn through the widest part by a single circular-saw less than 3 feet, allowing for the axle of the saw-blade.

In the case of Indian hardwoods circular saws will not in actual practice cut more than about a quarter of their diameter, 18 inches being a large cut for hard timber.

By having two saws working, one immediately above the other, a cut of 4 feet to 4 feet 6 inches can be obtained. For squaring logs, or converting into planks, thick scantlings, or sleepers, two circular saws may be placed parallel to each other, the timber passing between the blades and becoming trimmed to the required dimensions at once.

The *band-saw* is a long continuous flexible steel ribbon with teeth on one edge ; it passes round two large revolving wheels, thus presenting a continuous cutting edge. Band-saws may work either vertically or horizontally. The band-saw has several advantages ; it can saw timber of large diameter, causes little waste, requires less motive power than the circular saw, and turns out as much work as a circular saw and more work than a frame-saw. On the other hand, the band-saw requires much care and skill in sharpening and adjusting, so that its use is not recommended where a skilled and experienced mechanic is not available : the breakage of the saws when entrusted to any but a skilled man forms an expensive item in the working of a band-saw.

Among minor types of machine-saws may be mentioned a saw shaped somewhat like a pit-saw and used for cross-cutting logs as well as for longitudinal sawing; this saw may be made of a portable nature for work in the forest. A portable machine-saw of similar type has been invented for felling trees, the steam being conveyed from a small portable boiler to the machine at the base of the tree in a flexible pipe.

SECTION VIII.—THE STACKING OF TIMBER AND FIREWOOD.

Until the produce of a felling area is disposed of it should be stacked so that it may season without being exposed to the attacks of insects or fungi, and, in the case of timber, without becoming warped or cracked. This stacking may have to be done either in the forest or in some central depôt: wherever the stacking is done it should be done in such a way as to occupy as little space as possible, while each class of material should be stacked separately in order to keep a correct account of the produce and to facilitate inspection.

1. *Stacking Timber in the Round.*

Timber in the round should be allowed to season slowly and regularly; hence it should be kept out of the sun if possible and placed in such a position that it will be freely exposed to the circulation of air on all sides. Timber should not be kept lying on the ground for any length of time, particularly if the ground is damp: it should be raised on billets of wood or kept off the ground by skidding (that is, blocks and other waste pieces of wood).

For more permanent stacking a convenient method is shown in Plate XV, fig. 3. The stacks formed in this way take up comparatively little room, while the logs can be withdrawn singly without breaking up the stack; there is also a free circulation of air round the timber. This method of stacking is as follows:—The lowest tier consists of the largest and heaviest logs, placed parallel to each other with the thick ends all pointing one way; the log should be raised at least a foot off the ground by skidding or billets of wood. The next tier is laid over these, the logs lying at right angles to those of the lowest tier; the third tier is placed similarly over the second, the logs lying in the same direction as those of the lowest tier, but with their thick ends pointing in the opposite direction, and so on for all the tiers in turn. The logs of each tier should be separated from those of the tier below and above them by a few inches of skidding. To remove any single log from the stack the skidding is removed and the log is pulled out.

2. *Stacking Sawn Material.*

In the case of thick scantlings the stacking may be done in the manner just described for round timber, except that skidding between the various tiers is not necessary unless individual pieces are required from inside the stack ; the lowest tier, however, should be well raised off the ground and placed on a perfectly level site, otherwise the scantling will become crooked in seasoning. An inch or two of space should be left between the scantlings in each tier.

Thin boards should, as soon as they are sawn, be laid flat one upon the other, in the form of a solid stack, on a perfectly level site ; stones or other weights should be placed on the top of the stack to prevent warping. When they have become partly seasoned they should be stacked like other scantlings with a small space between each board in a tier (*vide* Plate XV, fig. 4).

There should be no delay in stacking sawn material after its conversion, as it is very liable to warp and split if left unstacked.

3. *Stacking Poles and Posts.*

Poles should be stacked horizontally, while still green, between two pairs of upright stakes, the thick ends of the poles pointing towards the road or side from which they are to be removed afterwards : they may be conveniently arranged in rows of ten each, by placing a thin straight stick between each row of ten poles near the thick ends (*vide* Plate XV, fig. 5). If necessary, heavy weights may be placed on the top of the stack to straighten the poles. If the stacks are to be left for some time a layer of skidding or a number of cross-pieces should be placed underneath them.

In India poles are often stacked vertically by leaning against a tree, with their thick ends on the ground : they are thus sheltered from sun and rain. Bamboos may also be stacked in the same way as poles, a common method of stacking them being shown in Plate XVI, fig. 1. Short

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STACKING OF BAMBOOS AND FUEL.

PLATE XVI.

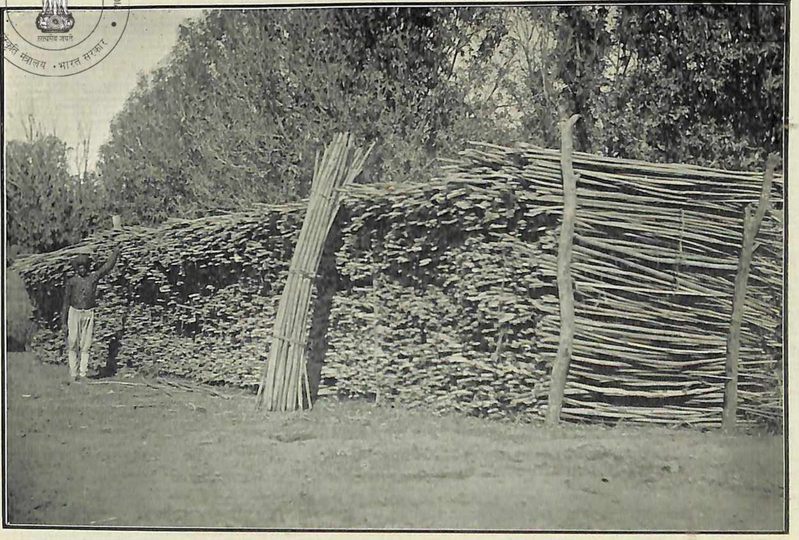

Photo. by Basti Ram,

1. STACKING OF BAMBOOS, LANSDOWNE FOREST DIVISION U. P.

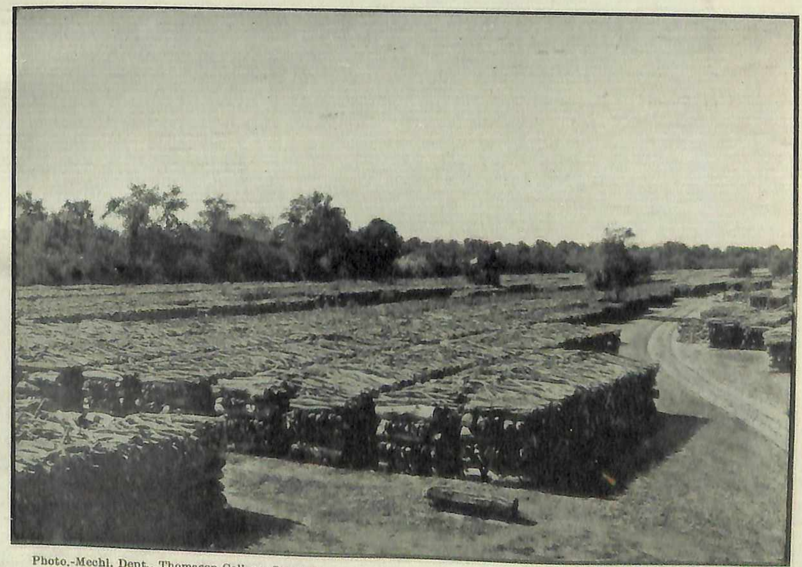

Photo.-Mechl. Dept., Thomason College, Roorkee.

2. FUEL STACKS IN CHANGAMANGA DEPOT, PUNJAB.

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posts may be stacked like poles or like fuel billets, the stacking of which will be described next.

4. *Stacking Fuel.*

In stacking fuel the chief points to be kept in mind are correct dimensions of stacks, close stacking, sufficiency of air-space between the stacks, and stability of the stacks. Damp places should be avoided, but if they are unavoidable the stack should be raised off the ground, as shown in Plate XV, fig. 6.

To ensure stability to the stack two pairs of upright stakes are driven into the ground at the same distance apart as the length of the stack; these may be further supported by struts or by withes passed round the stakes and between the billets during stacking, as shown in Plate XV, fig. 6. Stability may also be attained by placing a certain number of the billets at the end of the stack longitudinally, as in Plate XV, fig. 7. The stacking should be done as closely as possible, all gaps being carefully filled up.

The dimensions of a stack should be such that its contents can be quickly estimated. Thus if the billets are two feet in length a convenient height would be five feet, this giving an area of 10 square feet for the end of the stack, so that if a large number of stacks of different lengths have to be measured the total length multiplied by 10 gives at once the total volume of the stacks. The height and breadth of the stack should always be kept constant. In stacking, allowance is sometimes made for shrinkage during drying by making the stack slightly higher than necessary at the time of stacking. Where large quantities of fuel are to be stacked in a limited space, the stacks should form long continuous lines, each pair of lines being separated from the next pair by a space wide enough to enable a man to walk between the stacks. This system is shown in Plate XVI, fig. 2, which shows the arrangement of stacks in the Changa Manga depôt, Punjab, which often contains over a million stacked cubic feet of firewood; in this depôt 2″ is allowed for shrinkage in the height of the stacks.

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CHAPTER IV.

Wood Depôts.

1. *General.*

Depôts are places where wood or other forest produce is stored until it is time for its disposal. Although in some parts of India depôts for the sale of minor forest produce exist, the most important depôts are for timber or fuel. Depôts may be classed broadly into forest depôts and sale depôts. The former are usually of a more or less temporary nature, and are intended chiefly for the collection and checking of produce prior to its despatch from the forest. Sale depôts are of a more permanent nature, and are usually situated in some central place where intending purchasers can conveniently inspect the produce for sale. Sale depôts, from their position, are divided into land and water depôts. In some parts of India the distinction can hardly be drawn, as timber depôts are often situated on land which is flooded during the rainy season and dry during the remainder of the year.

2. *Land Depôts.*

In selecting a site for any land depôt care should be taken to provide for convenient ingress and egress: the depôt land when selected and acquired should be demarcated by conspicuous and permanent marks, otherwise encroachment from outside is liable to occur.

If the produce to be stored consists of fuel or timber liable to deteriorate if subjected to periodic wetting, it is essential that the ground should be well drained and not liable to inundation. Where, however, the timber to be stored will not suffer through periodic flooding, land subject to inundation is not entirely unsuitable, though it is objectionable if it renders the examination of logs difficult: hence on such land the area should be divided into sections separated by raised paths, so that intending purchasers can obtain access to any lot of logs from one of the raised footpaths. This system is followed in the large Government teak timber depôt at Rangoon, a land depôt which is partially inundated for several months in the year.

In depôts intended for scantlings or fuel it is often necessary to erect sheds for the protection of the material; in this case great attention should be paid to close stacking and economy of space. Sheds are also necessary for valuable material such as sandalwood, for charcoal, and for most kinds of minor produce. Depôts for all such small material, which can be easily removed, should be provided with a high fence and a gate which can be locked at night.

3. *Water Depôts.*

Water depôts may be established in a river, in still water, or on the sea-shore. River depôts are always attended with some risk owing to sudden rises due to floods, and are therefore unsuitable for long storage of timber. A place should be selected where the current is slack, a backwater for choice, and the logs should be enclosed by a boom, usually formed of logs chained together end to end. The bank should be stable, so that stout posts may be fixed at intervals for the mooring of rafts or smaller lots of timber, while specially firm posts or trees are required for fixing the boom.

Depôts in still water may be either natural lakes or ponds, or may be artificially constructed, the water being admitted by a channel leading from the floating-stream or river down which the timber has been transported: the channel should be wide enough and deep enough to allow the timber to be floated into the depôt.

A sea-shore depôt should be well sheltered, and should not be exposed to the open sea, while the beach should have a gradual slope. Wood should not be stored for any length of time in the water owing to the risk of marine borers. There is a typical sea-shore depôt at Port Blair in the Andamans; it is sheltered from both monsoons, and is situated on a low shelving beach, the water at low tide being nowhere more than a foot or two in depth. This depôt is surrounded by a fence on the landward side, reaching as far as low-water level.

4. *Management of Depôts.*

Every depôt should be in charge of a responsible person, whose rank will depend on the importance of the depôt. The depôt-keeper should be assisted by one or more guards whose duty it is to prevent theft or loss from any cause. All logs or scantlings brought into the depôt should be measured and numbered, their numbers, measurement, and description being entered in detail in a register of receipts. The numbering can be conveniently done by means of punches or numbering hammers; it is sometimes customary to stamp a special mark at either side of the number to prevent any figure being added. Where the serial numbers are commenced afresh each year, the year should also be marked to prevent confusion. The logs or scantlings on reaching the depôt are separated into various size and quality classes and divided into convenient lots for sale. The number of logs in each lot will depend largely on local circumstances, but where small dealers have to compete against more wealthy traders it is advisable not to have the sale lots too large, otherwise the small dealers cannot afford to compete. The procedure with regard to firewood is somewhat similar, the firewood being separated according to size and quality and stacked in separate stacks, each of which has its own number. Where numbers are stamped on timber or other produce with punches or hammers, it is advisable also to paint on the numbers conspicuously, so that they may be readily seen. The numbers of the depôt lots and symbols denoting quality or size classes should also be conspicuously marked.

When timber is sold at a depôt and the price has been realized the timber should be marked with the sale hammer, and the particulars of such timber should be entered in a sale register. Details of timber or other produce disposed of in any way should be entered in a register of receipts and issues, in the column of disposals or issues, which should agree with the column of receipts in the register. In some cases, particularly in the case of fuel and sandalwood, it will often be found that the volume or weight of a certain lot disposed of will be less than it was when it was received in the depôt, this loss being due to shrinkage or loss of weight in drying. In such a case the loss is written off in the column of disposal as wastage by shrinking or drying, so that the total disposed of will agree with that received in the depôt. The depôt registers should be balanced at least once a month, and should agree with the cash accounts and with the bills issued during the month for produce disposed of.

Complete stock of the depôt should be taken periodically, at least once a year. To facilitate stock-taking and to enable wastage to be checked at frequent intervals, a "section system" is in operation in some of the fuel depôts of the Madras Presidency. The depôt is divided into three sections, which we may call A, B, and C, for each of which a separate set of registers is kept. The quantity of fuel received in any one section is approximately enough to meet one month's demand. Sales are allowed only in one section at a time, so that when sales are going on in section A, section B is full, and section C is receiving fuel from the forest. As soon as a section is emptied its accounts are closed.

In the case of fuel, bamboos, poles or other produce required for daily consumption in small quantities, sales by fixed rates are the usual rule: in such cases the tariff rates should be clearly marked up on a board in the depôt. Receipts for produce purchased should be of a prescribed form, and should be serially numbered: manuscript receipts on odd pieces of paper should never be allowed.

When a sale takes place at a depôt the purchaser should be required to remove the produce purchased within a reasonable time, failing which demurrage should be charged. Unless such rules are enforced the depôt is likely to become a storing-ground for the timber of miscellaneous persons; such timber not only occupies space, but is liable to cause confusion. One of the most important points in depôt management is to arrange the timber in proper order, and in such a way that any log or lot of logs can be removed without displacing other logs. There is nothing more confusing than a depôt in which the logs are thrown down in heaps without any attempt at arrangement; in such a case the stock can never be properly checked, nor can loss be discovered until it is too late.

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PART II.

UTILIZATION OF MINOR FOREST PRODUCE.

Under minor forest produce is included all kinds of forest produce other than timber and firewood; it comprises animal, vegetable, and mineral products, and is therefore very varied in kind as well as in value.

We may conveniently deal with the principal classes of minor produce under the following heads :—

I.—*Grass.*
II.—*Leaves used for fodder, litter and manure.*
III.—*Fibres and flosses.*
IV.—*Oil seeds.*
V.—*Tans and dyes.*
VI.—*Distillation products and extracts.*
VII.—*Gums, resins, and oleo-resins.*
VIII.—*Indiarubber and gutta-percha.*
IX.—*Drugs, spices, and fish-poisons.*
X.—*Edible products.*
XI.—*Materials used for basket-work and matting.*
XII.—*Minor products used in the manufacture of paper.*
XIII.—*Miscellaneous minor products of vegetable origin.*
XIV.—*Animal products, including hunting, fishing and elephant-catching.*
XV.—*Mineral products.*

CHAPTER I.

Grass.

The utilization of grass is, when considered from the point of view of grazing and fodder, one of the most important factors in maintaining the agricultural prosperity of India, and therefore merits careful study, more especially as its utilization may, under certain conditions, be very harmful to the forest itself. We may conveniently consider the subject under the heads of (1) grazing, (2) cut fodder, (3) fibre-yielding and thatching grasses, and (4) grasses from which oils are distilled.

SECTION I.—GRAZING.

1. *Dangers arising from Forest Grazing.*

Although forest grazing under ordinary circumstances is most injurious to the welfare of the forest, still it is in most parts of India so closely connected with the agricultural customs of the country that it has to be submitted to, often to the detriment of successful forest management. The chief dangers arising from forest grazing may be summed up as follows :—(1) Young seedlings become crushed and trampled, while the soil in many cases becomes hardened by the tread of the grazing animals ; on steep slopes the earth becomes loosened and dislodged ; (2) seedlings and saplings are browsed down ; this is particularly the case towards the end of the dry season when the young plants have sent out their first flush of new leaves, while the grass is still dry and uneatable ; (3) the removal of grass and other herbaceous vegetation exposes the soil and removes manurial matter ; the removal of the latter, however, is to some extent compensated for by the manure afforded by the animals.

2. *Advantages of Forest Grazing.*

Although the disadvantages of forest grazing far outweigh its advantages, still there are exceptional circumstances under which a certain amount of controlled grazing may even be beneficial. Thus grazing tends to keep down rank grass and undergrowth; this lessens the danger from fire, and may even assist in freeing seedlings which would otherwise be suppressed.

Good results may also follow the wounding of the soil which accompanies grazing; this is particularly the case in coniferous forests where the thick layer of needles on the ground sometimes retards reproduction until the soil is wounded by the feet of grazing animals. In the teak forests of Burma grazing by elephants may do a great deal of good in breaking down bamboos and promoting the natural regeneration of teak.

3. *Factors on which the Amount of Damage by Grazing depends.*

Although grazing and browsing are not strictly speaking the same, it is convenient to include the two together, and in common parlance grazing often includes browsing. Where the context below indicates it, therefore, grazing may be taken to include browsing. The damage caused by grazing and browsing varies greatly under different conditions; the chief factors which influence the extent of damage are as follows :—

(1) KIND OF CATTLE.

The most destructive of all animals are *camels* and *goats*. Camels nibble off the top shoots of young trees, and owing to their height and long reach are capable of doing great damage by browsing. Camel grazing is often much aggravated by the fact that it takes place in poor desert forest where the damage done is considerably greater than in well-stocked forest. Goats are destructive mainly owing to their habit of eating almost everything that comes in their way, bending down saplings in order to reach the tender shoots. Goat grazing is prohibited by law in most European countries, and where rights to goat grazing exist in India they should if possible be commuted. *Sheep* are less destructive than goats, as they prefer grass, and will not eat anything else unless the grass is very coarse and dry. *Buffaloes* may do considerable damage by crushing young growth, owing to their weight and size, while on steep slopes they are apt to lay bare the roots of trees by trampling the ground. In the plains and low hills, provided there are sufficient water-courses with grass and other vegetation on either side, the damage done to the forest may not be great, as the buffaloes prefer to remain near the streams. *Cows* and *bullocks* are, for their size, probably the least harmful of all stock, as they prefer grass if they can get it; owing, however, to their immense numbers, they are the source of the great bulk of damage done by grazing in India. *Elephants* do damage by breaking down poles and saplings, plantations in particular suffering from their ravages. In bamboo forest elephants may do great damage by breaking down the bamboos where these are of value. Other animals are not sufficiently abundant to take into account.

(2) SEASON OF GRAZING.

The season during which grazing is most required by the agriculturist depends on local circumstances. In many parts of the country the dry season is the season of forest grazing, owing to the scarcity of fodder; in many rice-growing districts forest grazing is required in the rains, as the cattle cannot be admitted into the fields while the growing crops are on the ground. The extent of damage done during each season depends on circumstances: thus in forests which are maintained for the production of bamboos, grazing during the rains, at the time when the new shoots appear, should be prohibited. Grazing does most harm towards the end of the dry season, when the grass is all dried up and is uneatable, while the seedlings and saplings of forest trees, which have sent out a new flush of leaves, are greedily attacked: this danger is not to be feared so much after the rains have started and there is an abundance of green grass. Grazing in the dry season often leads to danger from fire, and it may therefore be necessary to close forest to grazing throughout the fire season.

(3) THE NUMBER OF CATTLE PER ACRE.

The greater the number of cattle admitted per acre, the greater will be the damage done to the forest, and it is therefore advisable to fix the maximum number of animals which may be allowed to graze over a given area. In this connection general figures are quite misleading, as the number of animals admitted must depend entirely on the type of forest, the period during which the forest is open to grazing, and on local conditions generally; such figures can only be arrived at by observing the effect of grazing a certain number of animals over a given area and fixing the number according to the degree of protection which it is necessary to afford to the forest. In some districts the area allotted is $\frac{1}{2}$ an acre per head of cattle, but this is incompatible with the safety of the forest. In Germany it is estimated that one cow requires 3 acres, a draught bullock $3\frac{3}{5}$ acres, a horse $4\frac{1}{2}$ acres, and a sheep $\frac{3}{10}$ of an acre.

The Darjeeling rules of 1885 fixed the minimum area at 5 acres per head of cattle. In Rawalpindi the number of bovine animals, ponies, and mules allowed is 1·6, and of sheep and goats 3·2 per acre, while in Ajmer-Merwara one head of cattle is allowed per acre where the forests are open to grazing for only 4 months in the year. In the Deccan one head per acre is the usual allowance.

4. *Regulation of Grazing.*

In order to minimize the injurious effects of grazing it is necessary to regulate it carefully; the chief measures to be taken are the following:—

(1) Coupes under regeneration should be closed to grazing long enough to allow the young plants to grow up out of reach of animals. In selection forests and other forests where the regeneration period is not limited, it is necessary to close certain areas in rotation. In every case the closed areas should be clearly marked off on the ground by means of pillars, boards, or other marks.

(2) The forest should not as a rule be kept open to grazing during the whole year, but should be closed for a certain number of months, the period of closing being that when the forest is most liable to suffer from grazing. In the Punjab it was found many years ago that areas closed to grazing for 9 months in the year brought higher returns than those kept open throughout the year.

Fencing is the safest method of closing areas of forest, though it is somewhat expensive. Ditches and live hedges, or temporary thorny fences, may also be employed, though they are more liable to be broken through than wire fences.

(3) There should be a responsible herdsman in charge of the cattle, and he should not have more cattle under his charge than he can look after; he should drive the cattle from place to place, and not keep them grazing too much in one part of the forest. In Bombay each grazier has to wear on his arm a numbered brass plate, showing he has authority to graze.

(4) The cattle should be provided with bells, so that straying animals may be detected.

(5) The number of cattle per acre should be limited so that the forest may not be over-grazed. The issue of brass number tablets to be fixed round the necks of the animals is a useful means of checking the numbers.

(6) In order to limit the extent of grazing, as well as to compensate for damage done and to produce revenue, grazing fees should be levied. These fees are usually fixed on a lower scale for local villages than for villages situated at a distance from the forest and for the cattle of professional graziers who visit the forests only at certain times of the year. The fees may be collected by permits, or an estimate of the number of cattle in each village concerned may be made periodically and fees levied in lump sums; the latter system is simple, and is perhaps the least oppressive system, but it has the drawback that correct figures as to the number of cattle are not easily obtained.

(7) In the case of cattle brought from a distance, it is often necessary to have enclosures for penning up the animals at night; this does not apply to cattle which can be driven back to their villages each evening.

SECTION II.—CUT FODDER.

1. *Grass-Cutting.*

As in the case of grazing, the cutting of grass removes a certain amount of manurial matter from the ground, and may also deprive young seedlings of shelter; its benefits, however, as a rule outweigh its disadvantages, particularly in freeing seedlings from suppression where they are unable to rise above the grass, and in diminishing the danger of fire. So beneficial is grass-cutting as compared with grazing, that wherever the former can be substituted for the latter it should be done. In permitting grass-cutting in the forest the use of scythes should be prohibited owing to the risk of cutting down young seedlings : if the cutting is done with a sickle, and if the grass-cutters exercise ordinary care, the risk of cutting seedlings is small. The quantity and quality of grass can be greatly improved by ploughing, frequently manuring the surface of the land, and weeding out coarse varieties of grass and other vegetation ; by systematic treatment of this kind the Government grass farms at Allahabad and elsewhere are capable of producing as many as 5 or 6 crops per annum, where originally the land was almost barren.

For immediate requirements, and where the grass is to be used in the neighbourhood of the forest, green fodder can be utilized, but where it has to be removed to a distance or stored for future use, it must first be converted into hay or silage.

2. *Hay.*

Grass intended for hay should be cut immediately after it flowers ; if cut after fruiting the grass is harder, more fibrous, and less nourishing, as much of its food material has been used up to form the seed. The grass should be cut in dry weather ; as soon as it is cut it should be spread out to dry, and on the approach of evening it should be collected into heaps to keep the dew from it. Next day it is spread out again in the sun and tossed up with wooden forks ; if sufficiently dry it should then be carted away and stacked, otherwise it should again be collected into heaps for the night and similarly dried and tossed up next day. Hay is about $\frac{1}{3}$ the weight of the grass from which it is made ; it should be greenish in colour, and should have the characteristic scent of fresh hay, without any trace of mouldiness. Hay should be built up in stacks, either circular with a conical roof, or shaped like a house with a pent roof ; the eaves should project further out than the base, and the roof should be thatched. Where damp or white-ants are to be feared the site of the stack may be first prepared by digging a trench round it, throwing the earth into the middle, and giving the site a slight slope up to the centre ; a layer of cinders 4 to 6 inches deep is then laid on the earth, and the stack is built up on the top of this, the eaves projecting over the trench. To keep the stack off the ground with a view to protecting it from damp it is often customary to build it on a foundation of large stones, or on a wooden skeleton platform raised a foot or two off the ground. In order to reduce its bulk for transport, hay may be pressed in special presses worked either by hand or by machinery : information on hay pressing will be found in Part IV, Chapter IX.

3. *Ensilage.*

Ensilage is a method of storing green fodder in an air-tight place, under pressure ; the most convenient method is to store the fodder in pits dug in the ground, these pits being known as silos. The success of this method of storing green fodder has been proved by many experiments in different parts of India : it has many advantages, not the least of which is that it may be made during the rains, for the fodder may be thrown into the pits quite wet. In making silage two precautions must be observed, first, the pit should be kept perfectly air-tight, and, second, there should be a certain amount of pressure on the pit ; if these conditions are fulfilled the manufacture of silage is an easy matter. The fodder employed may be of almost any kind, the coarsest and rankest grass being converted into tender succulent fodder in the process ; a mixture of different kinds of fodder may also be ensilaged in the same pit. The process of ensilage depends on the fact that green fodder when stored in an air-tight place undergoes chemical change by fermentation.

Silos are rectangular pits varying in dimensions, a useful size being depth 8 feet, measurement at the surface 26 feet by 9 feet and at the base 24 feet by 7 feet, the sides thus sloping slightly : the pits should be dug in stiff soil so that air may be excluded. The fodder itself, if very coarse, should be cut into moderately short pieces to ensure close packing. When the pit is filled to the top all the earth dug out of it should be spread over the fodder and rammed tight down : the contents of the pit sink for several days afterwards, and the covering should be examined frequently, all cracks being closed up. Sometimes matting is placed over the fodder before the earth is heaped on, but this is not essential. Permanent silo pits may be constructed with masonry or wooden sides, but the ordinary pit is quite sufficient and is cheaper. The pit is ready for opening from 3 to 6 months after being filled, but may be kept closed for several months longer : the contents of the pit should be used quickly after being taken out. Silage is usually greenish-yellow or greenish-brown in colour, and has a peculiar odour; it is sometimes objected to by cattle at first, but they usually get over the dislike, while in many cases they devour the fodder greedily from the first.

Over-ground silos may be constructed of masonry or of wood. Experiments at Pusa have shown that a cheap over-ground silo made of bamboo-work plastered over both inside and outside with mud can be made at a cost varying from R150 to R200. Such a silo is circular in plan, being 24 feet high by 18 feet in diameter, and is covered with a light thatched roof. For loading and unloading purposes it is provided at intervals of 6 feet up the sides with windows 3 feet by 2 feet, which can be closed tight.

SECTION III.— FIBRE-YIELDING AND THATCHING GRASSES.

None of the Indian grasses supply fine textile fibres, but a few of them are suitable for cordage and matting. The two most important grasses in this respect are the *bhaber*, *baib*, or *sabai* (*Ischœmum angustifolium*), and the *munj* (*Saccharum Moonja*). The former grows plentifully on the bare slopes of the outer Himalayas, as well as in parts of Bengal and in the Peninsula ; it is largely used for rough ropes and for mats, long-fibred *bhaber* grass being preferred. There is an extensive manufacture of *bhaber* mats at Shahjehanpur in the United Provinces, these being known as " Shahjehanpur matting."

The *munj* grows along river-beds and other low-lying places : the fibre is obtained from the long sheaths which envelope the stems, and is used for rope-making and for the manufacture of the durable matting known as munj-matting. The stems are used for basket-work, large verandah-chicks, the ceilings of verandahs, and similar purposes.

The *khus-khus* grass (*Vetiveria zizanioides*, syn. *Andropogon muricatus*) yields from its roots a fibre which is made into aromatic scented mats hung over doors and windows and kept wet to afford coolness in the hot weather.

The fibrous stems and leaves of the "elephant-grass" (*Typha elephantina*) are used for ropes, baskets, and matting.

Grass for fibre or thatch should be cut when quite ripe, as it is then most fibrous ; it should not, however, be left uncut for long after it has ripened, as it is liable to deteriorate by rotting. The grass should be cut regularly every year, as it falls off in quantity and quality if left uncut.

One of the most important uses of the more fibrous grasses is that of thatching, for which various species are used, the chief of which are *Imperata arundinacea* (syn. *I. cylindrica*), *Saccharum Narenga*, *Erianthus Ravennæ*, and *Heteropogon* (*Andropogon*) *contortus* (spear-grass).

SECTION IV.—GRASSES FROM WHICH OILS ARE DISTILLED.

The chief scented grasses of India belong to the genus *Cymbopogon*, the most important species being *C. Martini* (syn. *Andropogon Martini*), the *rusa-oil grass* or *geranium grass*. This grass grows wild in Central India, the United Provinces, and the Punjab. The scented rusa-oil is obtained by distilling the grass with water, and is used in perfumery and soap-making, much of it being exported to Europe: it is also largely used to adulterate attar of roses, while internally it is used as a tonic and in cases of fever. Commercial rusa-oil is apt to be adulterated with oil of turpenine or linseed and other oils.

The *lemon-grass oil* of commerce, used in perfumery and soap-making, is obtained from the *lemon-grass* (*Cymbopogon citratus*, syn. *Andropogon Schœnanthus*, Linn.) by distillation with a small quantity of water. The *citronella grass* (*Cymbopogon Nardus*, syn. *Andropogon Nardus*) also yields a scented oil, known as *oil of citronella*, whose manufacture and uses are similar to those of *C. citratus*.

Details regarding the distillation of oil from oil-grasses will be found on pages 270 and 271.

CHAPTER II.

Leaves used for Fodder, Litter, and Manure.

SECTION I.—LEAVES FOR FODDER.

The custom of lopping trees for fodder is a common one in India, the best fodder leaves being those which are still young and tender. The practice is an extremely harmful one, as it not only damages the trees and produces a gnarled branch-system, but also deprives them of nourishment, removes a considerable proportion of their assimilative organs, and robs the soil of what would eventually become manurial matter in the shape of dead leaves; moreover the timber of habitually lopped trees is liable to be misshapen and unsound. In spite of its bad effects, lopping has to be tolerated in many cases owing to the existence of rights to practise it; in such cases wherever the lopping is extensively and regularly done measures should be taken to regulate it in such a way that the least possible damage is done to the forest. The following are the principal measures which may be taken :—

(1) The upper branches of the trees should be left intact for 5 to 10 feet, only the side branches being cut; these should be cut with a smooth clean section, and flush with the stem. (2) Lopping should not be allowed over the whole forest annually; the forest should be divided into blocks which should be opened in a regular rotation of two or more years. (3) Lopping should be confined if possible to inferior species, the more valuable trees being left intact; if this is done the lopping may in certain cases even be beneficial to the forest. (4) Lopping should not be carried out on ridges and exposed slopes, where as much leaf covering as possible should be maintained. (5) Advantage should be

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taken of fellings, cleanings, and thinnings to obtain as much fodder as possible by lopping the branches of the newly-felled trees: coppice coupes in particular can in this way be made to supply a large amount of green fodder.

The number of different species lopped for fodder in India is very great: the following are a few of the commoner species used:—

Acacia arabica, *A. modesta*, *Acer cultratum*, *Adina cordifolia*, *Ægle Marmelos*, *Æsculus indica*, *Artocarpus Lakoocha*, *Bauhinia* spp., *Betula utilis*, *Bridelia retusa*, *Butea frondosa* (for buffaloes; not eaten by goats or camels), *Cassia Fistula*, *Cedrela serrata*, *Celtis australis*, *Dalbergia latifolia*, *Erythrina* spp. (for buffaloes), *Ficus* spp. (many give good elephant fodder), *Flacourtia Ramontchi*, *Garuga pinnata* (good elephant fodder), *Grewia* spp., *Hardwickia binata* (an excellent fodder, good for horses), *Holoptelea* (*Ulmus*) *integrifolia*, *Melia indica* (chiefly for goats and camels), *Millettia auriculata* (chiefly for buffaloes), *Moringa pterygosperma* (chiefly for camels), *Morus serrata*, *Odina Wodier* (good elephant fodder), *Olea ferruginea*, *Ougeinia dalbergioides*, *Populus* spp., *Prunus Padus*, *Pterocarpus Marsupium*, *Pterospermum acerifolium*, *Putranjiva Roxburghii*, *Quercus* spp., *Salix* spp., *Schleichera trijuga*, *Shorea robusta* (for buffaloes; lopping now forbidden in Government forests), *Spondias mangifera*, *Sterculia colorata*, *Streblus asper*, *Terminalia belerica*, *T. tomentosa*, *Ulmus Wallichiana* (planted near hill villages for fodder), *Zizyphus* spp.

SECTION II.—LEAVES FOR LITTER AND MANURE.

The custom of lopping branches of trees for litter and manure is practised in various parts of India; the twigs and leaves are either dug or ploughed into the soil in a fresh state, or else burnt in order to enrich the soil with ashes. A large number of different species of trees, shrubs, and other plants are employed for furnishing manure, those with milky juice being often preferred for green manure. In the Himalayas conifers as well as broad-leaved species are lopped for litter and manure, but in Government forests the lopping of valuable species is prohibited wherever possible. In Bombay the lopping of branches is largely carried out for *ráb* cultivation, that is, the manuring of rice nurseries by burning on the surface of the soil a mixture of cowdung, leaves and branches of trees, straw, grass, and pulverised earth; this special form of rich manuring is carried out owing to the absence of early rains and the occurrence of a short but heavy rainy season, circumstances which make it necessary to sow the rice late and to force the plants as much as possible while the rain lasts.

Where lopping has to be tolerated it should be regulated in the manner described in the last section.

In some localities, particularly in the Himalayas, leaves are collected off the ground for litter, that is, bedding for cattle. The best litter is yielded by the needles of pines, which are fibrous and absorbent; the needles of other conifers, and the leaves of certain broad-leaved species, especially oaks and rhododendron, are also used. In Bombay *Casuarina* needles are prized for litter, and are systematically collected. The removal of dead leaves and needles is most injurious to the forest, as it deprives the soil of its natural manure: experiments in Europe have shown that where dead leaves are annually removed from the ground for several years in succession the loss of increment in the trees may amount to over 50 per cent. on poor soils, the loss being less marked on rich soils and where the leaves are removed at intervals of a few years instead of every year. The practice of removing dead leaves is one which should be prohibited wherever possible, but where it has to be allowed it should be regulated in the following way: (1) it should not be allowed on poor soils, exposed ridges and slopes, or in open forest, but should be confined to rich soils where the leaf-canopy is more or less complete; (2) it should not be allowed in the same place every year, but only in certain blocks opened in rotation; (3) it should be allowed only during the first half of the season of leaf-fall, so that part of the year's leaf supply may remain on the ground; (4) advantage should be taken of roads, paths, fire-lines, beds of streams, and similar places from which leaves may be removed without damage to the forest.

CHAPTER III.

Fibres and Flosses.

In this chapter fibrous grasses are not included, having been already dealt with in Chapter I.

SECTION I.—FIBRES FROM STEMS.

Fibres of sorts are yielded by the *liber* (so-called inner bark) of all woody species, several yielding fibres strong enough to be twisted into rope, but few giving fibres fine and strong enough for textile purposes. The methods of extracting the fibre vary considerably with different species, and experience alone can determine how it should best be done: the process of separating the fibres is technically known as "retting." The living bark alone should be used, and not the outer dead bark. Some barks require to be soaked in water for a time, and then beaten or scraped clean, but the fibres of others, for example those of *Calotropis gigantea*, are damaged by immersion in water, and require to be separated without previous soaking.

By far the majority of fibre-yielding woody plants belong to one or other of the natural orders *Malvaceæ*, *Sterculiaceæ*, *Tiliaceæ*, *Leguminosæ*, *Asclepiadaceæ*, and *Urticaceæ*.

Among the *Malvaceæ* may be mentioned *Thespesia populnea*, *T. Lampas*, *Kydia calycina Hibiscus* spp., *Abutilon* spp., *Sida* spp., *Urena lobata* and *Adansonia* spp.

The *Sterculiaceæ* include some good fibre plants, notably *Sterculia urens*, *S. villosa*, *S. colorata*, and *Helicteres Isora*, yielding strong cordage fibres, and *Abroma augusta*, a shrub with fine silky fibre like hemp.

The chief fibre-yielding plants of the order *Tiliaceæ* which are of forest importance belong to the genus *Grewia*, most of the species of which give strong fibres suitable for cordage or rope-making. In the North-West Himalayas the fibre of *Grewia oppositifolia* is much used; the branches are cut from July till March (that is, at all seasons except in

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spring), and are then soaked for one month to 40 days in water, after which they are dried and beaten on stones, the bark being then stripped off and the fibres separated out.

The jute of commerce is obtained from two species of *Corchorus* (*C. capsularis* and *C. olitorius*, order *Tiliaceæ*); it is largely cultivated in India, and the fibre is separated by soaking in water.

Several of the *Leguminosæ* give strong fibres, suitable for rope or rough cordage, for example *Bauhinia racemosa*, *B. Vahlii*, *Acacia leucophlœa*, *Ougeinia dalbergioides*, *Desmodium tiliæfolium*, *Spatholobus Roxburghii*, *Butea frondosa*, *Sesbania* spp., and the branches of *Hardwickia binata*, which is frequently pollarded to produce shoots which will yield suitable fibre. The "sunn-hemp" is obtained from *Crotolaria juncea*, a leguminous plant much cultivated in the plains of India; the fibre is separated by soaking for a day or two in water, and then washing well.

The chief fibre-yielding plants among the *Asclepiadaceæ* are *Calotropis gigantea*, *C. procera*, common in alluvial sandy beds of streams, *Orthanthera viminea*, a leafless plant common in the river-beds of the Siwaliks, sub-Himalayas, and elsewhere, and *Marsdenia tenacissima*, which yields a strong silky fibre known as "rajmahal fibre" obtained by cutting the stems into sections, splitting and drying them, steeping them in water for about an hour, and then scraping the fibres clean with the nails or with a stick.

Among the *Urticaceæ* are various fibre-yielding plants of importance, including two plants largely employed in paper-manufacture, *Streblus asper* and *Broussonetia papyrifera*. The well-known "Rhea" fibre or "China-grass" is obtained from *Bœhmeria nivea*, while the "Ramie" fibre is the product of *B. nivea* var. *tenacissima*. A good flax-like fibre is produced by *Girardinia heterophylla* known as the "Nilghiri nettle," which is found in many parts of India. The hemp-fibre is obtained from *Cannabis sativa*, which is largely cultivated in India. Among species which yield fibres suitable for ropes and cordage are *Ulmus Wallichiana*, *Trema* spp., *Ficus* spp., *Antiaris toxicaria*, *Villebrunea* spp., *Debregeasia* spp., and others.

Among fibre plants which do not belong to any of the above natural orders may be mentioned *Careya arborea* and *Cordia Myxa*, furnishing bast fibres suitable for cordage, and *Linum usitatissimum*, the flax plant, from which linen is manufactured: this last, as well as some of the plants

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mentioned above, are not of forest importance, but are nevertheless mentioned as examples of some of the better-known fibre plants.

SECTION II.—FIBRES AND FLOSSES YIELDED BY FRUITS.

The most important fibre-producing fruit is that of the cotton plant. Among forest trees and plants there are a few which produce silky fibres in their fruits; these fibres are commercially known as "flosses" or "silk-cottons," and although they are usually too short to spin they are largely used for stuffing pillows. Among the best known flosses are those produced within the capsules of *Cochlospermum Gossypium*, *Bombax malabaricum*, *Eriodendron anfractuosum*, and *Calotropis gigantea*. The true "kapok" floss is yielded by *Eriodendron anfractuosum*, and is exported from Java in considerable quantity: it is not commercially exported from India, where the tree is planted chiefly for ornament. The well-known "Coir" fibre, largely used for ropes, mats, and other purposes, is obtained from the thick fibrous rind of the cocoanut.

SECTION III.—FIBRES YIELDED BY LEAVES.

Good cordage fibres are produced from the leaves of certain palms, for example *Arenga saccharifera* and *Caryota urens* (the "kitul" fibre, obtained from the petioles of the leaves). The famous Manilla-hemp is the fibre obtained from the outer parts of the sheathing leaf-stalks of *Musa textilis*, a plantain indigenous in the Phillipines and cultivated in some parts of India. The "Sisal" fibre is yielded by the leaves of *Agave sisalana*, an American plant cultivated in India. Various other species of *Agave* yield fibres, known generally as "aloe fibres;" the least important of these, as a fibre-plant, is *Agave americana*, the plant so commonly cultivated for ornament in gardens and used as a hedge plant. Pineapple leaves produce a fine strong fibre, said to be a possible substitute for flax.

CHAPTER IV.

Oil Seeds.

Many seeds of forest trees produce oils of economic importance. The oil expressed from the seeds of *Schleichera trijuga* is used locally for cooking and burning, and has been found suitable for soap-making. Oil extracted from the seeds of *Bassia latifolia* is used for cooking and burning by jungle tribes, and is sold for soap-making. *Bassia butyracea* is known as the "Indian butter-tree:" an oil known as *phulwa* oil is obtained from the seeds by beating them to the consistence of cream and placing this in a cloth bag, on which a weight is laid until all the fat and oil is expressed; this oil is used as a substitute for and an adulterant of *ghi*. In the cold weather the oils of both these species of *Bassia* are solid. The fat of *Bassia latifolia* and *Bassia longifolia* is to be found on the market both mixed and separately under the name of "Illipe butter," but this term is now so generally applied to all Indian fatty seeds that it has ceased to have any distinctive value.

"Chaulmugra oil," which is obtained from the seeds of *Taraktogenos Kurzii*, is used for leprosy and skin diseases, and is also taken internally as a tonic. "Kokam butter" is an oil obtained from the seeds of *Garcinia indica*, and is used for food and as a medicine. The seeds of *Mimusops Elengi* give an oil used in cooking, lighting, and in medicine. Those of *Pongamia glabra* give an oil used in medicine and also for lighting: it is a somewhat poor lighting oil, and is therefore usually mixed with sesamum or other oil for the purpose. *Juglans regia* gives a good oil from the kernel of its fruits. A bitter acrid oil is obtained from the seeds of *Melia indica* by boiling or by pressure, and is used medicinally; it is sometimes used for burning, but smokes disagreeably. The seeds of *Givotia rottleriformis*, a tree of Southern India, give an oil valuable for lubricating fine machinery. Wax is obtained from the seeds of *Rhus succedanea*, the lacquer-tree of Japan, which is found in the

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Himalayas: this wax is used for manufacturing candles in Japan. Another well-known wax-producing tree is *Sapium sebiferum*, the Chinese tallow-tree, which is commonly planted in India; the seeds are coated with a white wax, which is separated by boiling in water, and is used in China and Japan for candles.

"Sál butter" is an oil obtained from the cotyledons of the seeds of *Shorea robusta*. The seed is husked and boiled, she oil being then skimmed off the top of the water: it is tolid and white in the cold weather, and is used for cooking and lighting. Cocoanut oil, which is obtained from the kernel of the cocoanut-tree, is largely employed in the manufacture of soap and candles, as well as for many domestic purposes. The dried kernel, known as "copra," from which the oil is extracted, forms an important article of trade.

The almond-oil of commerce is yielded by the kernels of *Prunus Amygdalus*; a somewhat similar oil is obtained from those of the apricot (*Prunus armeniaca*). The kernels of *Prunus eburnea*, which is common in Baluchistan, have recently been reported by a chemical firm in England to be a possible source of an inferior oil of almonds. From the seeds of the common climber *Celastrus paniculata* is expressed a red or yellow oil used medicinally and for burning in lamps: by destructive distillation along with certain spices it yields an oil known to pharmacy as "oleum nigrum." The seeds of *Mesua ferrea* are rich in a reddish-brown oil used for burning and for applying to sores.

Owing to their scattered nature and the consequent high cost of collection for commercial purposes on a large scale, the forest oil-seeds can seldom compete with oil-seeds produced from field-crops, for example linseed, mustard, rape, cotton, sesamum and other crops. As a rule, therefore, their use is more of local than of general commercial importance.

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CHAPTER V.

Tans and Dyes.

SECTION I --- GENERAL.

The name tannin is given to a class of organic substances which have the property of combining with albumen and gelatine to form an insoluble compound which will resist decay; for this reason raw hides treated with tannin become converted into the substance known as leather. Another property of tannic acid is to turn iron salts black; this property is made use of in the manufacture of ink. Tannin is found chiefly in parenchymatous tissue, such as bark and young wood, certain fruits and leaves, and also in the galls formed on leaves and stems by insects: tannin also occurs in the extracts obtained from the wood of certain trees, the most important of which is *Acacia Catechu*, which produces the extract known as cutch, the manufacture of which is described on pages 274 to 276.

Dyes are obtained from the wood, bark, roots, flowers, fruits and leaves of many trees and other plants.

SECTION II.—TAN-YIELDING BARKS AND WOODS.

Bark contains most tannin in its inner living tissues: hence bark intended for tanning should be taken from fairly young stems which have not reached the stage of producing hard outer bark, as this not only contains little or no tannin, but often gives a dark colour to the leather. Vigorous stems contain more tannin in their bark than stems of poor growth. The most suitable stems from which to obtain tannin bark are coppice shoots grown on short rotation: the bark may be taken off standing trees, newly felled trees, or from wood which has become more or less dry. In the case of standing or newly felled trees the bark should be stripped off at the beginning of the growing season, because it is then most easily taken off and contains most tannin; the most convenient method is to take the bark off in sections with an axe, billhook, or special barking scalpel. In the case of more or less dry wood, the wood has to be cut into billets, and may have to be steamed before it can be barked; not only does this give extra labour, but some of the tannin, owing to its solubility in water, is apt to be washed out during the steaming, unless care is taken that the steam is superheated.

After the bark has been removed it should be dried in such a way that rain will not get at it and wash out the tannin. In fine weather this is best done by leaning the pieces of bark against each other, with or without the support of a roughly made trestle, so as to form a kind of pent roof, the outer side of the bark being uppermost; in wet weather the stacks of bark require to be protected by a covering of thatch or other material. In fine weather the bark becomes sufficiently dry in two or three days, and is then exported; the chief object of drying the bark is to lighten it and reduce its volume.

As bark and wood are bulky articles to transport to long distances, various methods have been devised for preparing tannin extracts, so that the tanning material may be reduced to the smallest bulk possible. The preparation of tannin extracts is described on pages 277 to 280.

Perhaps the four most extensively used tanning barks in India are those of *Acacia arabica*, *A. leucophlœa*, *Cassia auriculata* and the mangrove *Rhizophora mucronata*.

Other important tanning barks are those of certain mangroves (*Bruguiera gymnorhiza*, *Ceriops Candolleana*, and *C. Roxburghiana*), *Cassia Fistula*, *Shorea robusta*, *Bauhinia purpurea*, *B. variegata*, *Acacia Suma*, *Garuga pinnata*, *Soymida febrifuga*, *Zizyphus Jujuba* (root bark), *Z. xylopyra*, *Rhus Cotinus*, *R. mysorensis*, *Odina Wodier*, *Terminalia tomentosa*, *T. Catappa*, *Eugenia Jambolana*, *Barringtonia acutangula*, *Bridelia retusa*, *Quercus incana*, *Buchanania latifolia*, *Lagerstrœmia parviflora*, *Anogeissus pendula*, *Engelhardtia spicata*, and *Phyllanthus Emblica*. Several of the wattle-trees of Australia (*Acacia* spp.) have been naturalized in India, and yield good tanning barks; the chief species are *A. dealbata*, *A. Melanoxylon*, and *A. decurrens*.

The preparation of tannin extracts from wood has hitherto not been carried out to any great extent except in the case of cutch; there are, however, other woods which give promise of yielding good tannin extracts, for example

Xylia dolabriformis, from the sawdust and waste wood of which extracts have been prepared experimentally.

SECTION III.—DYE-YIELDING STEMS AND ROOTS.

Dyes are obtained from the bark, wood, and in some cases the roots, of many trees and other plants. Many of the barks used for tanning, as well as wood-extracts such as cutch, are used for dyeing, owing to the fact that tannic acid combined with salts of iron gives a black, grey, purple, or green colour, while many barks and woods in themselves contain colouring ingredients which can be extracted by decoction. Most of the colouring matter of bark is contained in the outer layers, and not in the inner living tissues as in the case of tannin. Most bakrs give a brown colour, and less commonly some shade of yellow. Brown dyes are produced from the bark of *Terminalia tomentosa*, *Shorea robusta*, *Hardwickia binata*, *Acacia arabica*, and others; that of *Acacia leucophlœa* gives a black or red dye, that of *Myrica Nagi* a yellow dye, and those of *Symplocos cratægoides* and *S. racemosa* a yellow or red dye. A yellow dye, used in Kashmir for dyeing woollen thread and fabrics, is extracted from the root-bark of *Datisca cannabina*, by boiling. Several woods give beautiful dyes, notably *Pterocarpus santalinus*, giving a salmon-pink dye known as "santalin," *Cæsalpinia Sappan* and *Adenanthera pavonina* a red dye, *Berberis* spp. *Artocarpus integrifolia*, and *Plecospermum spinosum* a yellow dye, and *Cynometra ramiflora* a purple dye. *Hæmatoxylon campechianum*, the "logwood" of commerce, is a native of the West Indies, and has been introduced into India; the wood gives a valuable black, violet, or deep red dye. The order *Rubiaceæ* produces several important dye plants, one of the best known being *Rubia cordifolia*, the madder or *manjit* plant, which gives a red, mauve, or brown dye; this plant is common in the Himalayas, whence it is exported. To the same order belongs *Morinda tinctoria*, of which the bark of the root is largly used for dyeing red and yellow. Among dye-plants which are not of forest importance the best known is *Indigofera tinctoria*, yielding the blue indigo dye.

Many plants, although not yielding colouring matter, are used in dyeing in the form of mordants to fix the dyes from other plants.

SECTION IV.—LEAVES AND GALLS YIELDING TANS AND DYES.

Some leaves are rich in tannin, particularly those of *Anogeissus latifolia*, *Rhus Cotinus*, and *Phyllanthus Emblica*. The leaves should be collected when they are mature, but before they change colour ; they should be quickly dried after collection and then ground into coarse powder for export. Leaves which turn dark in drying are rich in tannin.

Dyes are obtained from several kinds of leaves : thus the leaves of *Terminalia Catappa* give a black dye, those of *Wrightia tinctoria* a blue dye, those of *Symplocos cratægoides*, *S. racemosa*, and *S. spicata* red or yellow dyes, while those of the teak tree give a dye of a red, orange, or yellow shade, which can be seen on bruising young teak leaves or placing them in methylated spirits. The "henna" dye, used for dyeing the nails, skin, and beard, is obtained from the leaves of *Lawsonia alba*, a common hedge plant.

Galls are found on several species of trees and shrubs, and are largely used for tanning and dyeing : some of the principal gall-bearing species are *Tamarix* spp., *Pistacia integerrima*, *Garuga pinnata*, *Acacia leucophlæa*, *Terminalia Chebula*, *T. tomentosa*, *Prosopis spicigera*, and *Pongamia glabra*.

Lichens are collected in the Himalayas and elsewhere for export ; they are used in the preparation of dyes as well as medicinally. The dyes known as litmus and orchil are derived from lichens of the genus *Rocella*, obtained partly from Ceylon. In the Himalayas lichens are collected from oaks and also from *Pinus longifolia* ; those collected from oaks are considered superior.

SECTION V.—FLOWERS, FRUITS, AND SEEDS YIELDING TANS AND DYES.

Dyes are yielded by certain flowers, such as those of *Punica Granatum* (Pomegranate), giving a light red dye, *Nyctanthes Arbor-tristis*, whose yellow corolla-tubes give an orange dye, *Chickrassia tabularis*, giving a red and yellow dye, *Michelia Champaca* and *Cedrela Toona*, yellow dyes, *Butea frondosa* and *B. superba*, yellow and orange dyes, and *Wrightia tinctoria*, an indigo dye. The flower-buds of *Ochrocarpus longifolius* give a red dye, and are used for dyeing silk. The flowers of *Woodfordia floribunda* are used for tanning leather, and also furnish a red dye used in dyeing silk and leather.

The "Arnatto dye" is obtained from the pulp surrounding the seeds of *Bixa Orellana,* originally introduced from America and now cultivated in India; this dye is largely used for colouring silks, giving beautiful shades of red and orange. The "Kamela dye" is obtained from the red glands on the surface of the fruits of *Mallotus philippinensis,* a small tree very common in most parts of India. The Kamela powder is obtained either in a dry state by shaking the capsules in a bag, or in a wet state by stirring them in water and collecting the sediment in the form of cakes; the dye is used chiefly for dyeing silk a bright orange colour, but as the cost of collection is high this dye cannot compete with artificial dyes. From the capsules of *Thespesia populnea* a yellow dye resembling gamboge is obtained.

The fruits of *Zizyphus xylopyra* are used to give a black dye to leather; those of *Acacia arabica* and *Diospyros Embryopteris* are used for tanning, and also yield brown and black dyes, while those of *Oroxylum indicum* are used in tanning and as a mordant in dyeing. The rind of the fruit of *Juglans regia* is a tanning material. The pods of certain leguminous plants furnish good tanning material, for example those of *Acacia arabica, Cæsalpinia digyna* known as "Teri" pods, and *C. Coriaria,* commercially known as "Divi-divi." The last-named is a native of the West Indies, though it is cultivated in some parts of India.

"Myrabolans" are the fruits of *Terminalia Chebula* and *T. belerica,* while those of *Phyllanthus Emblica* are sometimes called "emblic myrabolans." These fruits are rich in tannin and are used for tanning and dyeing. The most important kind of myrabolan is that furnished by *Terminalia Chebula.* The myrabolans of *Terminalia belerica* are of less value, and hardly repay the cost of collection and transport.

CHAPTER VI.

Distillation Products and Extracts.

SECTION I.—OILS AND TARS.

Mention has already been made (*vide* page 112) of the chief commercial products obtained by the distillation of wood; we are here concerned rather with certain oils and other substances which are of interest in India.

There are several Indian trees from the wood of which oils and other substances are distilled: the chief of these are *Santalum album*, yielding the sandalwood-oil used in perfumery and medicine, *Cedrus Deodara*, from which is extracted deodar-oil, used for skin diseases and rheumatism and also for smearing over the inflated skins used in crossing rivers, *Pinus longifolia*, from which *chir*-tar is obtained by destructive distillation, *Pinus excelsa*, from the roots of which an oil is extracted in Kashmir and used to anoint the arms and legs to keep off insects in the rice-fields, *Tectona grandis*, from the heartwood of which tar is obtained by a process similar to that by which *chir*-tar is manufactured, and *Aquillaria Agallocha*, from which an attar is extracted. The manufacture of sandalwood-oil and *chir*-tar is described in detail in Part IV. The wood of *Aquillaria Agallocha*, a large tree found in the hills of Eastern Bengal, Assam, and Burma, contains masses of dark-coloured resinous fragrant wood, known as *agar-wood* ("eaglewood"), which are cut out and used as a burning incense by the Parsis and Arabs. This dark-coloured fragrant wood is not used for distillation, the light-coloured wood in which the fragrant masses are embedded, and known in Assam as *dums*, being used for this purpose; the oil called *agar-attar*, is obtained by distilling chips of this wood with water, and is used as a perfume.

SECTION II.—CAMPHOR.

Camphor is the general name given to a variety of substances, all of vegetable origin and similar in their main

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characters. Ordinary camphor is a colourless semi-transparent substance with a crystalline structure and a sharp aromatic odour. Crude camphor contains an oil, which has to be separated from the camphor during the refinement of the latter. Besides being a valuable drug, camphor plays an important part in the manufacture of celluloid and of explosives as well as of other commercial products. There are three main sources of camphor, (1) common or Laurus camphor, obtained from the tree *Cinnamomum Camphora*, a native of China, Japan, and Formosa, and much planted in India and elsewhere in the East, (2) Borneo or barus camphor, obtained from a large Dipterocarp *Dryobalanops aromatica*, a native of North Borneo, Sumatra and Labuan, and (3) Ngai or *Blumea* camphor, obtained from the composite plant *Blumea balsamifera*, which is very common in jungle clearings in Burma, and extends into Eastern India, the Malay Peninsula, and South China. Of these three camphors the first-named is by far the most important commercially, being the most abundant source of the world's supply: it is also the cheapest of the three. Borneo camphor is the most costly, being obtainable only in small quantities and being highly valued for medicinal purposes in India. Ngai camphor, which is manufactured in China, is cheaper than Borneo camphor but more expensive than common camphor. It is almost unknown in Europe, but is used in China for the manufacture of fine qualities of ink, as well as in medicine and for ritualistic purposes. A brief account of the methods employed in distilling camphor will be found on pages 272 and 273.

SECTION III.—PERFUMES.

The flowers of many species are employed for the extraction of perfumes, for example *Canangium odoratum*, *Mesua ferrea*, *Michelia Champaca*, *Nyctanthes Arbor-tristis*, *Rosa* spp., *Jasminum* spp., *Acacia Farnesiana*, and *Clerodendron inerme*. A scented oil is extracted from the flowers of *Ochrocarpus longifolius*: the flowers are collected before they are open, as they are of little use after they have fully opened.

CHAPTER VII.

Gums, Resins, and Oleo-Resins.

SECTION I.—GENERAL ACCOUNT.

Gum is a more or less viscous substance which exudes from cracks or wounds in the bark of many trees, shrubs, and climbers; gums are, botanically speaking, degradation products of the cell-wall, and occur chiefly in the cortex. Gums are classified into various types according to their physical and chemical properties. *Gum arabic*, obtained chiefly from *Acacia Senegal*, is a valuable form of gum which is readily soluble in water, and can therefore be employed for adhesive purposes. *Gum tragacanth* is insoluble in water, but has the property of absorbing large quantities of water and swelling up to a considerable bulk; it is not produced by any Indian species, but an inferior substitute for tragacanth known as *bassora gum* (in India called *Katira*) is obtained from several species, for example *Cochlospermum Gossypium*, *Sterculia* spp., *Bombax malabaricum*, etc.

Gums are largely used as mucilage, in calico printing, sizing paper, confectionery, medicine, and for other purposes. It is of great importance that the gum collected from different species should not be mixed, and that it should be free from bark, earth, and other impurities. As gums collected in India and exported to Europe frequently consist of several kinds mixed, and are often full of impurities, the value of Indian gums in the European market is not so high as it might become with more care in collection and preparation. The viscosity of gums is tested by noting the number of seconds required for 50 cubic centimetres of a solution of given strength (usually 10 per cent.) to flow through a cylindrical tube with a narrow aperture of fixed calibre below, highly viscous solutions taking longer to pass through than those of low viscosity.

Resins, like gums, are degradation products of the cell-walls, but also occur as derivatives of starch. Resin may occur either in the wood or in the cortex : in the latter case it is secreted in special resin ducts, and in the former it may occur either in resin ducts or in the vessels and other wood-tissues. Resins are insoluble in water, but are soluble in alcohol: they are inflammable, burning usually with a smoky flame, and are divided into three classes, (1) true resins, which may be hard or soft, (2) gum-resins, which contain a gum soluble in water, and (3) oleo-resins, containing an essential oil.

The resins of pines and of the *Dipterocarpeæ* are collected by making incisions into the wood; other resins, as well as gums, are collected either from spontaneous exudations or from wounds in the bark. In the case of certain species of *Gardenia*, a gum resin is exuded from the leaf-buds and is collected for sale. As the method of collection from the bark differs materially from the method of collection from the wood, we may deal with each separately.

SECTION II.—EXUDATIONS FROM THE BARK.*

1. *Methods of Collection.*

Collection from the bark may be carried out either from spontaneous exudations, as in the case of the gum of *Anogeissus latifolia*, *Acacia arabica*, *A. modesta*, and *Sterculia* spp., and the resin of *Boswellia serrata*, or from wounds in the bark, as in the case of the gum of *Bauhinia retusa*, the gum-kino of *Pterocarpus Marsupium* and *Butea frondosa*, and many other gums and resins.

Spontaneous exudations take place particularly when the bark cracks with prolonged heat or as a result of unhealthiness; thus after a long dry hot season large quantities of gum are exuded, particularly from the more unhealthy trees, while after a forest fire these exudations are especially copious.

Collection from wounds in the bark is carried out in two different ways. The first or common method is by making gashes through the bark, the details of the tapping depending on local custom. Plate XVII, fig. 1, shows the common method of tapping *Odina Wodier* in Northern India, by gashes made with an axe, a system also employed for other

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* Bark is here used in the popular, not the strictly botanical, sense, and includes what is botanically known as the cortex.

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species which require to be tapped in this way. The second method of tapping is by cutting thin slices off the surface of the bark. This latter method is employed only in the collection of gamboge, obtained as described below from *Garcinia Morella.*

2. *Chief Kinds of Gums and Resins.*

The following is a brief description of the principal kinds of gums and resins found in India :—

Acacia arabica gives a gum, somewhat similar to gum arabic, which is largely collected and used in native medicine, dyeing and cloth printing. The gum exudes naturally during the hot weather, and is usually collected during February, March, and April. Old trees yield more gum than young trees, the amount varying from 1 lb. from trees 10—15 years old to 2 lbs. from trees 20—40 years old. The gum from young trees, however, is clearer, whiter, and more valuable than that obtained from old trees.

Acacia Senegal yields the true "gum arabic" of commerce, largely used in calico printing, in medicine, for giving lustre to silk, and for many other purposes. The tree occurs in Sind, the Punjab, and Rajputana; it is also common in many parts of Africa. The gum collected in India is so often mixed with other gums that it is commercially less valuable than the African gum.

Anogeissus latifolia produces a gum much used in calico printing; it is inferior in strength to gum arabic for adhesive purposes.

Bauhinia retusa yields the "semla gum," a clear gum resembling gum arabic, but not so useful, being only imperfectly soluble in water: in Europe its commercial value is low. The trees are usually tapped once in every four or five years, tapping being done twice a year, in March and April and again in September and October, the collection of the gum taking place in May and June and again in November and December; by this means the monsoon and winter rains are avoided. Gashes about 4 inches apart are cut through the bark and just into the sapwood all over the trunk, and on branches of 6 inches girth and over; the gashes are cut as much as possible horizontally, the cutting being done with a light axe with a blade about 2 inches broad. The average yield of gum per tree is about 10 lbs.

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TAPPING FOR GUM AND WOOD-OIL. PLATE XVII.

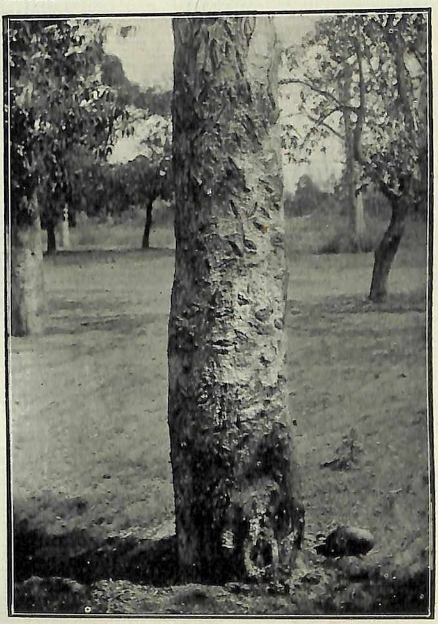

Photo. by Basti Ram.

1. METHOD OF TAPPING ODINA WODIER FOR GUM IN NORTHERN INDIA.

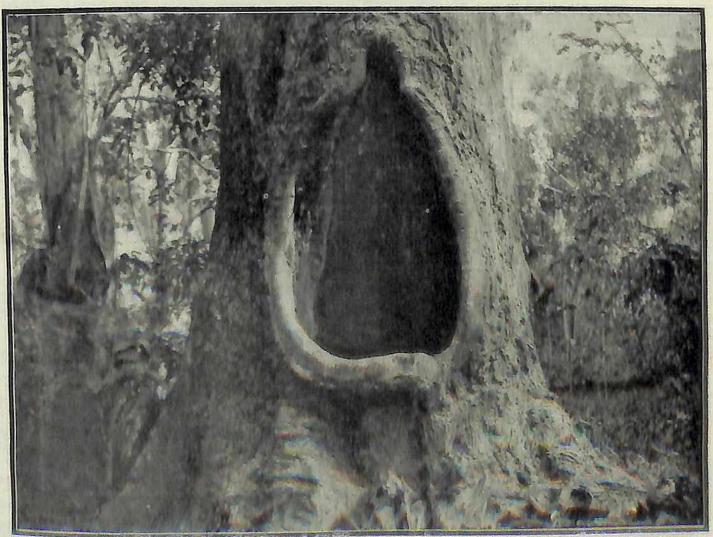

Photo.-Mechl. Dept., Thomason College, Roorkee.

Photo. by J. J. Rorie.

2. LARGE KANYIN TREE (DIPTEROCARPUS ALATUS) WHICH HAS BEEN TAPPED FOR WOOD-OIL; BURMA.

[To face page 180.

Boswellia serrata yields a transparent gum-resin from wounds and cracks in the bark ; this is used as medicine and is burnt as incense.

Buchanania latifolia gives a gum which is too insoluble to have much commercial value.

Butea frondosa yields a ruby-coloured gum obtained from gashes in the bark, and to some extent spontaneously ; this gum, which is known as "Bengal kino," is soluble in water, and is used as an astringent in medicine.

Cochlospermum Gossypium yields a white gum, insoluble in water, which is used in native medicine and is also largely used by shoe-makers. It is sometimes sold as *katíra,* though the true katíra or gum-tragacanth is produced by species of *Astragalus* not found in India.

Dammar is a trade name given to a certain group of resins : the true dammar is obtained from *Agathis loranthifolia,* a conifer found in Borneo, Sumatra, and elsewhere. In India there are altogether six substances commercially known as dammar—(1) *Black dammar* is a shining deep reddish-brown resin obtained from *Canarium strictum* by making vertical cuts in the bark and setting fire to the bottom of the tree by lighting a pile of firewood round the base. The dammar begins to flow 2 years after burning and flows for about 10 years, between April and November : the resin is collected in January. This dammar is not of great commercial value ; it is used in India for varnish, after dissolving in turpentine. (2) *Sál dammar* is a resin obtained by tapping the *sál* tree, *Shorea robusta ;* its supply is now limited owing to the stoppage of tapping in Government forest, where much damage was formerly done through tapping operations. (3) *Rock dammar* is a yellow or whitish resin obtained from *Hopea odorata,* and used for making copal varnish. (4) *White dammar* is a valuable resin obtained from *Vateria indica,* a large tree of the Western Peninsula ; it is used for manufacturing varnish. (5) *Green dammar* is a dark-coloured resin obtained from *Shorea Tumbuggaia* and used in medicine. (6) *Pwenyet dammar** is a black resinous substance, a combination of various gums and resins collected by certain species of bees of the genus *Melipona* (*Trigona*) and moulded into a mass, usually in the hollow of trees. This resin, which is believed to be collected

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* This substance might possibly be classed as an animal product, but as it is one of the substances known as *dammar* it is convenient to deal with it here.

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from *Hopea odorata* and various species of *Dipterocarpus*, is much used in Burma for caulking boats.

Garcinia Morella furnishes the "gamboge" of commerce, a yellow gum-resin obtained from incisions in the bark, or by cutting a thin slice off the surface of the bark and allowing the gamboge to collect and harden on the exposed surface. It is used in Europe for water-colour paints, in India for caste-marks, and in Burma for dyeing silks a yellow colour.

Melanorrhœa usitata yields a black oleo-resin or natural varnish from cuts made in the stem and chief branches; this varnish is largely used in Burma, under the name of *thitsi*, for lacquer work, varnishing, caulking boats, and in medicine.

To collect the varnish a few V-shaped incisions are made through the bark on different sides of the tree a few feet from the ground, and into the apex of each V a small bamboo tube 4 to 6 inches long is driven, the tubes being made to slope downwards. The varnish collects in these tubes, which are emptied periodically, as a rule every 5 or 6 days, the tube being replaced in the wound. Generally the varnish ceases to flow after about three visits to the tree, when fresh incisions are made a few inches above the old ones. This process is repeated till the incisions extend a considerable distance up the trunk of the tree.

Odina Wodier yields a brown clear brittle gum used in paper sizing, cloth printing, and in native medicine; it is soluble in twice its weight of water.

Pterocarpus Marsupium yields the "gum-kino" of commerce, a bright red astringent gum-resin containing about 75 per cent. of tannic acid, and much used in medicine. The tapping is done by means of a series of V-shaped incisions an inch wide in the bark, about 8 or more in all, one above the other and some 9 inches apart: these are connected by a vertical cut running through the apex of each V, and leading to a bamboo tube placed at the bottom to receive the juice. The gum begins to flow in liquid form as soon as the cuts are made, and continues flowing for about 12 hours. The liquid is then taken to a drying shed, strained, and poured into shallow trays to a depth of about $\frac{1}{8}$ of an inch; these trays are placed on shelves closed in with muslin to keep out dust. Drying takes 2 weeks in dry weather and 3 to 4 weeks in wet weather. The tapping should be done late in the afternoon and the tubes removed early next morning to prevent the gum drying on the tree or in the tube. Large trees give a smaller yield, but produce heavier gum than small trees: a tree 6 feet in girth yields about 3 lbs. of liquid gum or 1 lb. of dry gum. It is considered safe to tap trees on alternate sides once in 5 years.

Sterculia villosa gives a clear white gum resembling that of *Cochlospermum Gossypium*, and, like it, is sold as "katíra" and used in native medicine.

Styrax spp. The "gum-benzoin," sometimes called "gum-benjamin," of commerce, a resin which is used as incense and in medicine, is obtained by incisions in the bark, from *Styrax Benzoin*, a small tree of the Malay Archipelago: it is represented in India by *Styrax serrulatum*, which gives an inferior gum-benzoin.

Among less important gums and resins which have local uses, may be mentioned those produced by *Acacia Catechu* and *A. modesta* (gum), *Bombax malabaricum* (gum), *Canarium sikkimense* (resin), *Eriodendron anfractuosum* (gum), *Eugenia Jambolana* (gum), *Feronia Elephantum* (gum), *Gardenia* spp. (gum-resin), *Lagerstrœmia parviflora* (gum), *Mangifera indica* (gum), *Melia indica* (gum), *Pentacme sauvis* (resin), *Shorea obtusa* (resin), *Soymida febrifuga* (gum), *Spatholobus Roxburghii* (gum), *Tamarix dioica* (gum).

SECTION III.—EXUDATIONS FROM THE WOOD.

Two different classes of exudations are obtained from incisions made into the wood, namely, the wood-oil obtained from certain species of *Dipterocarpus*, and the resin obtained from pines: these will be described in turn.

1. *Wood-oil from Species of Dipterocarpus.*

These wood-oils are usually classed as oleo-resins, consisting as they do of a volatile oil holding in solution a resin. The two chief wood-oils are *Gurjun-oil*, or *Kanyin-oil*, obtained from *Dipterocarpus turbinatus* and *D. alatus*, and *In-oil*, from *D. tuberculatus*; the former is produced in larger quantity and is better known than the latter. *Gurjun-oil* is used for mixing with rotten wood to make torches, as a preservative of wood and bamboo work, for the manufacture of paint and varnish, and in medicine. The uses of *In-oil*, which is a thicker substance than *Gurjun oil*, are more local; in Burma it is used for making torches, for waterproofing bamboo baskets, and for caulking boats.

In tapping for *Gurjun oil* a semi-circular hole is cut from 3 to 5 feet from the ground, the width of the cut being about 1 foot 6 inches to 2 feet, and the height from 1 foot to 1 foot 6 inches: this cut slopes downwards into the tree, being hollowed out to a depth of about a foot in order to hold the wood-oil which exudes. This hollow is filled with dry leaves and grass which are set alight and kept burning for about a quarter of an hour, after which the fire is extinguished, and the oil commences to exude. The first collection of oil is usually, if not always, made before burning the cut, fire being applied when the oil ceases to flow. The oil is collected every 3 or 4 days, fresh fire being applied, sometimes each time the oil is collected and sometimes at intervals of about 10 days: the upper surface of the hollow is also re-chipped 3 or 4 times during the season, which lasts from November to May. The yield of oil is about 15 to 20 lbs. per tree per season; trees growing in dense shade, however, yield less oil than those exposed to full sunlight. The tapping of trees in this manner damages them considerably, as will be seen from Plate XVII, fig. 2, showing a large tree which has been subjected to tapping in this manner.

The collection of *In-oil* is carried out in a similar manner, except that the hole has to be rechipped oftener owing to the thicker consistency of the oil as compared with *Gurjun-oil*. As *Dipterocarpus tuberculatus* yields a useful timber the tree is not tapped in localities where forest-conservancy has been introduced.

2. *The Tapping of Pine-trees for Resin.*

The crude resin which is obtained by tapping various species of pine yields by distillation two important commercial products, oil of turpentine and colophony or rosin. The two principal resin-producing countries at present are France and the United States of America. Russia produces a fair quantity, and exports turpentine to the United Kingdom. Austria produces a small quantity, not sufficient for her own requirements. In India systematic tapping of *Pinus longifolia* has been carried on for several years in the Himalayas; this species does not produce the best quality of resin, the turpentine being inferior to that of several other pines for making varnish owing to the difficulty with which it dries, but as the tree is plentiful and accessible the tapping of it is highly remunerative, while the existing demand for the turpentine for medical purposes testifies to its purity. With improved methods of distillation the turpentine of *Pinus longifolia* may prove to be a quicker drying oil than it has been found to be in the past The Indian pines which produce the best quality of resin are *Pinus Khasya*, found in Assam and Burma, and *P. Merkusii*, occurring to a limited extent in Burma : these two pines are for the most part situated in remote places, so that the cost of transport has hitherto largely prohibited their remunerative tapping. *Pinus excelsa* produces resin less freely than *P. longifolia*, but the turpentine and colophony obtained from it are of rather better quality.

The resin of conifers occurs mainly in resin-ducts which run in a vertical or horizontal direction through the wood. The vertical ducts are, for tapping purposes, more important than the horizontal ducts, the latter being narrower than the former. The horizontal resin-ducts are found inside the medullary rays, and run with them into the cortex. If a pine-tree be blazed, therefore, resin will be found to exude both from the wood and from the cortex, the flow being more copious from the vertical resin-ducts in the wood than from the horizontal ducts in the wood and cortex. According to Mayr's researches, there is always more resin in the heartwood than in the sapwood : on the other hand the flow of liquid resin is more copious from the sapwood than from the heartwood. The reason of this is that when the sapwood becomes converted into heartwood the resin-ducts become blocked up, the flow of resin being thereby obstructed.

These physiological facts have an important bearing on practical resin-tapping, for it is obvious that the highest yield of resin will be obtained by tapping the sapwood and by severing the largest possible number of vertical resin-ducts. In actual practice it is neither necessary nor advisable to tap more than 1 inch deep.

Resin-tapping is carried out in various ways, but the method found most satisfactory in the Himalayan forests is based on the French system, and will be described somewhat in detail. It may be mentioned first that the native method of tapping resembles that, just described, of tapping the *Dipterocarpeæ* for wood-oil, except that in the case of pine-tapping fire is not employed; the resin flows into a basin-like cavity cut into the heartwood, and is periodically scooped out. Needless to say, this system inflicts great damage on the tree without producing a higher yield than would be obtained if the cut were made only into the sapwood.

The method of tapping *Pinus longifolia* trees in the Naini Tal Forest Division, United Provinces, is as follows :—

With a curved gouge-chisel 8 inches broad (measured on the curve) a cut is made through the bark and into the wood of the tree, sloping slightly upwards, at a height of about 6 inches from the ground. Into this cut a rectangular piece of galvanised iron 6″ × 2½″ is hammered, and forms a curved lip. For some distance above this lip the outer bark is scraped off, and immediately below the centre of the lip a nail is driven in; on this nail is hung an unglazed clay cup like a flower pot, of about a pint capacity, near the top of which a hole is bored to hang it on the nail. The top of the cup is covered, all except immediately below the lip, with a piece of bark or an earthenware lid to prevent the ingress of fragments of bark and dirt and the evaporation of the oil of turpentine. Plate XVIII, fig. 2, shows an earthenware lid on the cup. Immediately above the iron lip a blaze 6 inches high, 4 inches broad, and ¾ inch deep is made with a sharp adze the head of which is 8 inches long, with a cutting edge 2 inches broad. Hitherto the blaze has been made rectangular in section, the adze having a straight cutting edge, but recently blazes of curved section have been tried, an adze with a curved edge being employed; the main object of this is to minimize the damage done to the tree by cutting as many resin-ducts as possible while making a wound which will heal in the shortest possible time. Plate XVIII, fig. 1, shows the appearance of a blaze of curved section during the first season of tapping, together with the cup, and immediately above it the iron lip, the object of which is to guide the resin from the blaze into the cup. The results of one season's working tend to show that the yield of resin is considerably higher in the case of blazes with a curved section than of blazes with a rectangular section.

As soon as the blaze is made resin begins to exude and trickle slowly down, falling on the lip and thence into the cup. Every 6 or 7 days the upper part of the blaze is freshened by the removal, with the adze, of a thin shaving of wood not more than 2½ inches in length. This is necessary as the resin dries on the blaze and clogs up the exposed ends of the resin-ducts; the freshening of the blaze promotes the free

TAPPING OF PINUS LONGIFOLIA FOR RESIN IN NAINI TAL FOREST DIVISION, UNITED PROVINCES. PLATE XVIII.

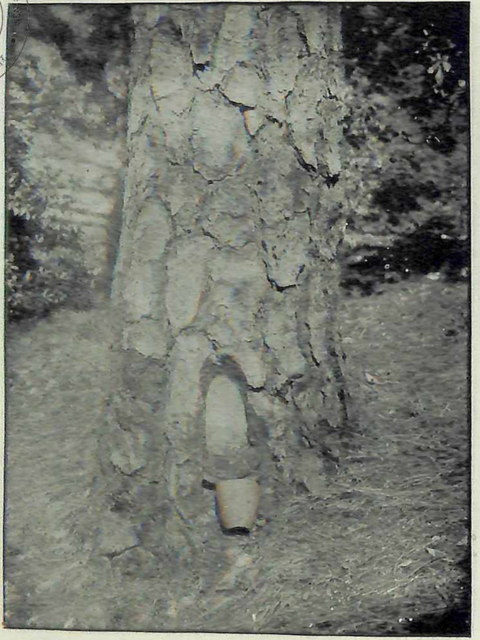
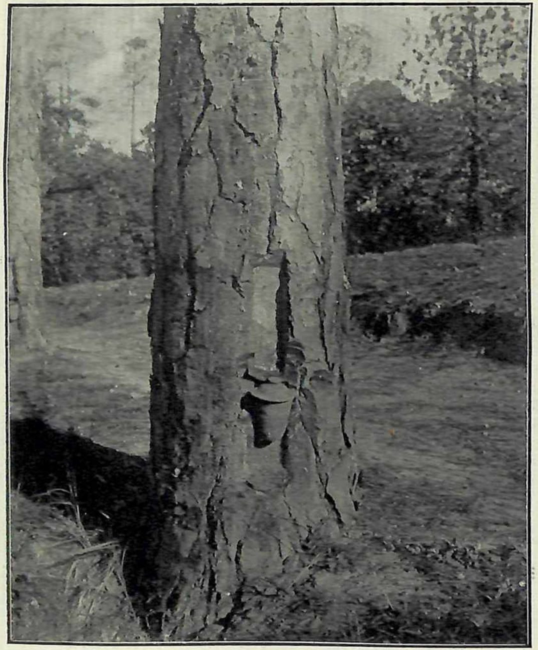


Photo.-Mechl. Dept., Thomason College, Roorkee.

BLAZE OF CURVED SECTION:
1ST SEASON'S TAPPING.



Photos. by Author.

BLAZE OF RECTANGULAR SECTION: 2ND SEASON'S TAPPING. CUP WITH EARTHENWARE LID.

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flow of resin again. This freshening of the blaze continues throughout the tapping season, which lasts from the beginning of March till the end of October, so that by the end of the first season the length of the blaze is about 1½ feet or slightly longer. As soon as the cups are full the resin is emptied from them into canisters or kerosene-oil tins by collecting coolies, the time varying from 10 days to a month according to season, aspect, condition of the tree, and other factors.

At the commencement of the next season the lip, nail and cup are moved up to within about 4 inches of the top of the previous year's blaze, and tapping is continued as before. The same process goes on for 5 years. By the end of the fourth season the blaze is about 6 feet high, so that during the fifth season a ladder has to be employed. Plate XVIII, fig. 2, shows the appearance of the blaze and the position of the lip and cup during the second season's tapping, and Plate XIX, fig. 1, the appearance of the blaze after 5 seasons, when tapping is completed. Plate XIX, fig. 2, gives a general view of tapping operations during the second season.

The number of blazes made on each tree is as follows :—

Trees over	6′	in girth . .	3 blazes.
,,	4′ 6″—6′	,, ,, . .	2 ,,
,,	3′ 6″—4′ 6″	,, ,, . .	1 blaze.

Trees under 3 feet 6 inches in girth are not tapped.

After a tree has been tapped for 5 successive years it is given a rest for 10 years, so that the tapping system of Naini Tal is based on a 15 years' rotation.

In the Chakrata Division of the United Provinces trees of a minimum diameter of 2 feet are tapped for 3 years in succession, an interval of at least 7 years being allowed before the trees are re-tapped. The initial blaze is made about 1 foot long, which is longer than necessary. The nail for supporting the cup is hammered in below the latter, the cup being pressed up against the lip to keep it in position. The blaze is freshened once in about 8 days, and becomes 2 to 2½ feet long by the end of the first season, and usually well over 6 feet long by the end of the third season.

In the Kangra Division of the Punjab the initial blazes are made only 3 inches high, these becoming 2 feet 6 inches long by the end of the first season. The blaze is elongated about 1 inch weekly from March till the beginning of the rains, ½ of an inch during the rains, and again 1 inch from the end of the rains till the end of October, when the season closes. The cups, which are 8 inches deep and 4 inches in diameter, are suspended by wires looped over nails driven into the tree on a level with the lip.

Resin flows most freely during the hot weather, the quantity exuded being much less during the rains and almost ceasing during the cold season ; in the Himalayas the resin-tapping season usually lasts from March till the end of October. The flow of resin is greater on the south side of the tree than on the north, and on hot southern slopes than on cool northern slopes. Although excessive tapping is injurious to the tree, and may even kill it, the quality of the timber, according to experiments carried out in America, is improved, becoming stronger and seasoning more quickly. In France it is sometimes the custom to kill by excessive tapping such trees as are to come under the axe in a short time ; the effect of this is to cause the trees to produce a large quantity of seed before they die, thus promoting good natural reproduction. This "tapping to death," as it is called, has recently been introduced in Naini Tal Division, trees which are to be felled being heavily tapped (one blaze for each foot of girth with one additional blaze) five years before they are felled. There can be no doubt that resin-tapping has its disadvantages : the chief of these are the loss of timber in the lower part of the tree owing to the presence of wounds caused by the tapping, and the danger from fire, as a tapped tree has its resinous wood exposed to the flames and suffers greatly. Hence systematic resin-tapping should never be introduced until fire-protection is assured. As regards the loss of timber, if tapping is carried out only for a few years immediately before the tree comes under the axe the loss is almost negligible ; in remote places, however, where the timber cannot be sold, there is no objection to periodic tapping for many years before the tree reaches its maximum size. Thus the extent to which resin-tapping should be carried out will depend largely on local conditions. With moderate tapping an average tree (*Pinus longifolia*) may be expected to yield from 5 to 12 lbs. of crude resin per annum. The highest yield is ordinarily obtained in the third and fourth years, the third year's yield being higher than that of the fourth year ; that of the fifth year is less than that of the fourth year, and that of the second year less than that of the third year but higher than that of the first year.

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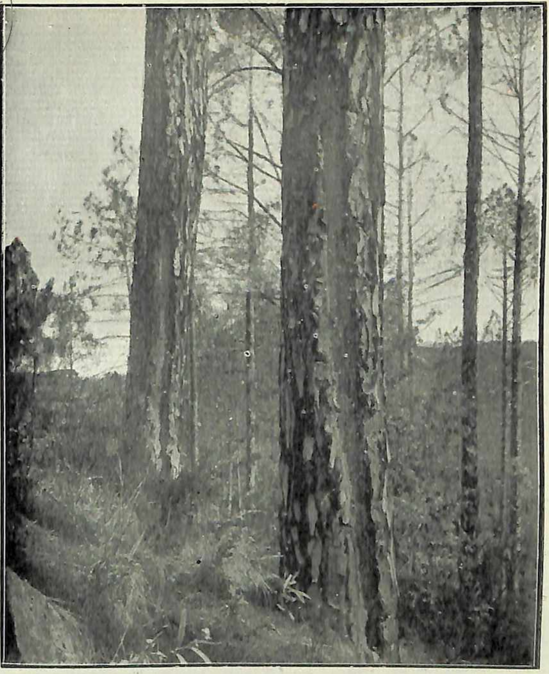

APPEARANCE OF BLAZE AFTER 5 YEARS, WHEN TAPPING IS COMPLETED.

Photo.-Mechl. Dept., Thomason College, Roorkee. Photos. by Author.

PINUS LONGIFOLIA FOREST, SHOWING GENERAL VIEW OF TAPPING OPERATIONS DURING 2ND SEASON.

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CHAPTER VIII.

Indiarubber and Guttapercha.

SECTION I.—GENERAL ACCOUNT.

Under this head are included two valuable commercial products, indiarubber or caoutchouc and guttapercha. Caoutchouc is a substance found in the milky latex of a large number of plants belonging chiefly to the orders *Euphorbiaceæ*, *Urticaceæ*, *Apocynaceæ*, and *Asclepiadaceæ*; the latex is found in the cortex, and extends into the leaves, roots, fruits, and other parts, but is not yielded by the wood. This latex consists of a watery medium in which are suspended not only caoutchouc but also particles of resin and other substances, while the liquid medium contains various salts, phosphates, and in some latices tannin. The latex after collection turns darker in colour and coagulates after a time which varies in different species. Various measures are adopted in the case of different latices to facilitate coagulation and separate the caoutchouc from the other constituents of the latex; the chief of these measures are washing and kneading, boiling, separation by a centrifugal machine, or treatment with various chemicals such as acids, of which acetic is the best, alum, mercuric chloride (corrosive sublimate), creosote, etc.

Chemically speaking caoutchouc is a hydro-carbon, that is, a compound consisting essentially of hydrogen and carbon: it is an elastic substance, impervious to water but not to gases, insoluble in alcohol, acids, and alkalies, and soluble in benzol, naphtha, bisulphide of carbon, chloroform, oil of turpentine, and some other oils. The substance known as vulcanite is a combination of caoutchouc and sulphur.

Many different rubber-producing plants are indigenous in India, by far the most important being *Ficus elastica* (Assam or Rambong rubber), an account of which is given below. Of recent years various climbers belonging to the order *Apocynaceæ* have received attention, particularly in Burma; the chief of these are *Parameria glandulifera*, *Urceola esculenta* (syn. *Chavannesia esculenta*), *Rhynchodia Wallichii*, *Ecdysanthera micrantha* and *Chonemorpha macrophylla*, but although these are reported to yield good rubber their

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commercial success is not yet assured owing to the difficulty and cost of collection.

Of exotic trees which have been introduced into India there are three which deserve special mention; these are (1) *Hevea brasiliensis* (Para rubber), order *Euphorbiaceæ*, a native of Brazil; this tree produces the best quality of rubber, but requires a moist, warm climate, (2) *Castilloa elastica*, order *Urticaceæ*, a native of Central America; it requires a climate neither too moist nor too dry, and is suitable for the coffee zone, (3) *Manihot Glaziovii* (Ceara rubber), order *Euphorbiaceæ*, which regenerates freely from seed and grows in a variety of climates, being well adapted for the plains; the yield of rubber in India, however, is poor.

Many other exotic species have been tried and are still under trial, but whether they will be a commercial success or not is a matter which only the future can decide.

The Para rubber has proved the most profitable tree for planting in the tropical regions of the East, and extensive plantations have been formed in the Straits, Ceylon, and the Dutch East Indies. In the Indian Empire there are fairly extensive areas under Para rubber in Southern India and in Burma, and the industry has every prospect of developing further in both these regions. A few particulars regarding this important tree are given on pages 192 to 198.

Indiarubber is an article which is employed for a large number of purposes, and since the development of the motor-car industry the demand for rubber for tyres has been in excess of the supply, with the result that good rubber commands a high price in the market.

Guttapercha differs from caoutchouc physically rather than chemically; it is a soft plastic substance when heated, but when cooled down is hard. When exposed to the air it is liable to oxidize and become brittle on the surface, but under water it is extremely durable, and as it is one of the best insulating substances known it is largely employed in the manufacture of submarine cables. Guttapercha is obtained from various species of the order *Sapotaceæ*, the chief of which is *Palaquium Gutta* (syn. *Isonandra Gutta* or *Dichopsis Gutta*), a tree of the Malay Peninsula.

SECTION II. RUBBER FROM *FICUS ELASTICA*.

Ficus elastica is a large evergreen tree found wild in the moist forest of the outer Eastern Himalayas, in Assam, and

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in Upper Burma, mainly in the Hukong Valley, where it has been much overworked; it flourishes best where the atmosphere is excessively humid. In Assam large plantations of *Ficus elastica* have been formed, and much experience has been gained regarding the best methods of propagating and tapping the tree. In its natural state it usually starts as an epiphyte, the seedlings growing in the forks of other trees, and subsequently sends down aërial roots which reach the ground. The tree may be reproduced artificially by seed, by layers, or by cuttings. The spacing of trees in plantations should not be less than 25′ × 25′ : this is by many considered too close, and triangular planting 35′ × 35′ and even wider spacing is sometimes adopted.

The following is the usual method of tapping adopted after several years' experience in the Charduar and Khulsi rubber plantations in Assam :—

The trees are cleared of creepers and rubbish and all undergrowth is cut down under them; bamboo mats are then laid down under the trees to collect any latex which falls, the mats being well dried before use, as green bamboo mats discolour the rubber. The tapper then ascends the tree and begins tapping from the highest branch, no branch less than 2 feet in girth being tapped; the cuts are made with a V-shaped gouge driven with the aid of a small wooden mallet, care being taken to make the cut just deep enough to reach the cambium but not to injure the wood. This gouge makes cuts 1¼ inches broad on the outside: the cuts are made horizontally 15 inches apart (the length of the gouge) on alternate sides of the branches and stem, extending more than half and less than two-thirds round. The latex flows for 2 or 3 minutes after tapping, some falling on the mats and some coagulating in the cuts; the mats are then removed to the next tree and used over and over again until thickly coated with rubber. Impurities such as bark, leaves, etc., should never be allowed to remain on the mats, but should be shaken off when the mats are removed from each tree. The rubber is pulled off the cuts usually on the third day after tapping: this rubber, together with the mat rubber, is taken to a godown, impurities are removed by hand, and the rubber is dried on shelves or hung over ropes, being put out in the morning sun for a quarter of an hour daily. When dry, the rubber is pressed by a screw-press into 18-inch cubes, each weighing 1 cwt.: after 24 hours these cubes are packed in cotton cloth, from which all starch has been washed, and

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sewn into double gunny bags, when it is ready for the market.

In the Assam plantations tapping starts in the middle of October and continues till the end of March. The greatest yield is obtained from the middle of November to the middle of January, that is, in the season of least growth; most latex flows in the early morning, the flow being less copious in the heat of the day and smallest in the evening. Rain is fatal to tapping, as the latex is washed away. The trees are tapped once only in a season, experiments having shown that a second tapping by re-opening the cuts produces a comparatively small yield. The minimum age at which trees may be tapped, and the safest interval, have not yet been ascertained definitely; it may be said generally that trees should not be tapped younger than 12 to 14 years, and that an interval of at least 2 years should be allowed between successive tappings, the new cuts being made between the old ones. The yield of rubber per tree varies greatly: in the Charduar plantation the maximum yield obtained from a single tree in 1905-1906 was nearly 8 lbs., but the yield from the Assam plantations is as yet small. A fair average yield, under proper working, for trees 50 years old may be taken to be 10 lbs.: from younger trees much smaller yields are obtained, averages of 1 to 2 lbs. per tree in a season's tapping operations being usual. Large yields are obtainable under the wasteful system, carried out by jungle tribes, of tapping the ground roots as well as the stems and branches, which has resulted in the extermination of the rubber trees in many remote tracts. The cost of preparing the ground and stocking one acre with rubber plants varies with local conditions, but should not be more than Rs. 40 to Rs. 50. The cost of collection and preparation of the rubber, including all charges, is in the Assam plantations from 4½ annas to 7 annas per lb.

SECTION III.—RUBBER FROM *HEVEA BRASILIENSIS*.

1. *General.*

The home of the Para rubber tree (*Hevea brasiliensis*) is in the Amazon valley in South America. It was first introduced into India in 1873, when a few plants were sent to Calcutta from Kew. It was not till 1875 that it was

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seriously talked of in Ceylon as a possible plant of economic importance; its extension throughout the East commenced to date from the early eighties, but was at first slow. Within recent years, however, the planting of Para rubber has proceeded by leaps and bounds, large areas having been planted within the past ten years in Ceylon, Malaya, Borneo, Java, Sumatra, Southern India, and Burma.

2. *Planting.*

Planting is carried out by clearing and burning existing jungle, and preparing planting holes 1½ feet deep and as wide as possible (2′ × 2′ being none too large). The seedlings may be planted out as soon as the seeds have germinated, or they may be raised in nurseries and planted out 9 to 12 months later, preferably in the form of basket plants. A common system is to " stump " the plants, that is to prune them down to within a few inches from the ground before transplanting them. The spacing of the earlier plantations was undoubtedly too close, and even now opinions differ as to the correct spacing to adopt. In the majority of cases a spacing of 20′ × 20′ is now generally adopted. Weeding and green or artificial manuring are carried out during the early years of the life of the plantation; in green manuring some authorities recommend only a surface dressing of herbaceous plants cut and thrown on the ground, and not dug in, as the digging is liable to injure the roots of rubber trees.

3. *Pruning.*

As tapping is generally confined to the lowest 6 feet of the trunk of the tree, and as trees which fork early increase more rapidly in girth than those which form an uninterrupted bole, the practice known as " thumb-nail " pruning is resorted to. The terminal bud is pinched out when the young tree attains a height of about 10 feet, forking being thereby induced. Further pruning may be necessary subsequently to check the formation of too many large branches. Pruning of the large branches does more harm than good.

4. *Principles of Tapping.*

Tapping commences when the trees have attained a girth of 20 inches, which is reached in 4 to 6 years. Rubber from very young trees is inferior. The latex tubes run mainly in a vertical direction, and are found chiefly in the inner part of the cortex, close to the cambium; hence any system of tapping should provide for oblique cuts, and the cortex should be cut right through. Horizontal cuts are not advisable, as the latex cannot drain off satisfactorily. The cortical tissue should be cut with an absolutely clean cut, not scraped or dragged in such a manner as to clog the latex tubes and form a rough surface over which the latex will not flow; the cut should be deep enough to reach but not to damage the cambium, and only the thinnest shaving should be pared off at each cutting. Many different tapping knives have been invented, and recently pricking instruments have come into vogue.

The principle of tapping *Hevea* trees depends on the phenomenon known as "Wound-response," which has not yet been observed in any other kind of rubber tree. This phenomenon, regarding which the first reliable results were obtained by Willis and Parkin, consists in the fact that although the first tap made in a *Hevea* tree yields comparatively little latex, the effect of the wound is to stimulate the production not only of a greater flow of latex, but also of a higher yield of caoutchouc, *in the immediate neighbourhood of the wound.* This increase is not observable 12 hours after first tapping; it is sometimes noticeable 24 hours after, but generally not for two days. Experiments have also shown that the yield goes on increasing for many consecutive tappings. This phenomenon leads to two important principles in tapping *Hevea* trees: (1) at each place of incision many successive tappings should be made, each in close proximity to the one preceding it, and (2) the interval between tappings is generally 2 days; in some localities 24 hours is found to give good results. As regards the number of tappings to be made, the tree itself is the best indicator, for the supply of caoutchouc eventually fails, a thin watery latex resulting, which will not pay the cost of collection; the tree then has to be given a rest. Generally a *Hevea* tree will stand tapping for 3 to 4 months.

The phenomenon of wound-response governs the methods of tapping *Hevea* trees, that is, tapping should be done by reopening old wounds, and not by making fresh incisions. An initial incision is made through the cortex down to the cambium, but without destroying the latter, and each subsequent tapping is made by shaving off a thin paring of cortex down to the cambium from the lower side of the initial groove. The thinner the paring of cortex removed at each tapping the better, for the longer the cortex can be made to last the greater, as a rule, will be the yield of rubber. With some of the modern tapping knives shavings $\frac{1}{20}$ of an inch or less can be obtained. Incisions were at first made by grooves of V-shaped section, but experiments have shown that a single slanting cut produces wound-response just as well, and hence tapping systems are based on simple oblique incisions. Formerly the latex was collected separately from each incision, but as this involves much labour it has been generally discarded in favour of collection at the base of the tree, cups being placed there for its reception. To assist the flow of latex cups are sometimes fixed at the upper ends of the cuts, from which water is allowed to trickle in small streams down the incisions. Tapping higher than 6 feet from the ground is not generally considered advisable because the yield from the upper part of the bole is comparatively small, and the use of ladders increases the cost of tapping. Tapping is done in the cool of the morning and evening, the flow of latex ceasing partially or entirely during the heat of the day.

5. *Tapping Systems.*

Many different systems of tapping *Hevea* trees have been employed in the past, but the two most widely employed in plantations now are the *spiral* and the *herring-bone.*

Spiral systems.—A spiral incision is made from a height of 6 feet to the base of the tree. A *full spiral* is one carried right round the trunk, and a *half-spiral* is one carried half-way round. Small trees require only one spiral, but an additional spiral can be added for each foot of girth; thus a tree 3 feet in girth could have three spirals (*vide* Plate XX, figs. 1 and 2). At each successive tapping, a thin paring of cortex is removed from the lower edge of the spiral, and the latex flows down the spiral into cups placed at its base and if necessary also at intervals up the spiral. The full spiral gives a higher yield than any other system and requires the least amount of labour, but it is the most drastic method and is therefore employed principally for trees to be removed in thinnings.

Herring-bone systems.—A vertical groove is made in the bark, extending from a height of 5 or 6 feet to the base of the tree. Oblique incisions up to 6 inches or more in

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length and about a foot apart are then made from this vertical groove upwards in a slanting direction. If these incisions are made alternately on either side of the vertical groove the system is known as the *full herring-bone*, and if only on one side of it, the *half herring-bone* (*vide* Plate XX, figs. 3 and 4). The latex is obtained from the oblique incisions, the vertical groove conveying it to a vessel placed at its base. At each consecutive tapping a thin paring of cortex is removed from the lower side of the oblique incisions, and this process goes on till all the space between the various oblique incisions has been used up. The half herring-bone is now generally preferred to the full herring-bone system, as it is less severe. By the half herring-bone system one quarter of the circumference of the bole can be tapped each year, the tapping of the tree thus extending over 4 years, by which time, so far as experience goes at present, the originally tapped area is again ready for tapping.

V-tapping, that is, tapping by V-shaped incisions, has been extensively employed, but has been largely discarded in favour of the herring-bone system. Where the V-shaped incisions are scattered over the trunk of the tree collection of the latex is laborious, as it has to be done separately for each incision, while the flow of latex does not continue so long as in the herring-bone systems (sometimes for not longer than two months), the tappable area becoming exhausted more quickly.

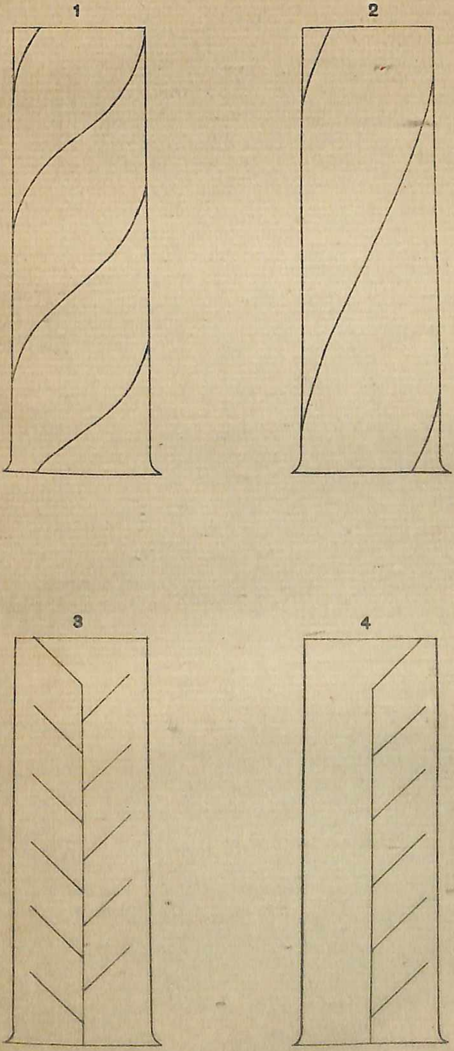
Pricking.—In order to prevent too much damage to the cortex, pricking instruments have been brought into use either in conjunction with, or as substitutes for, paring instruments. In some cases good results have been obtained by pricking methods, but further experience is necessary before determining whether or not they are preferable to the usual paring methods.

6. *Yield of Rubber.*

The yield of rubber varies greatly according to locality, and the size, age and general condition of the trees. In Malaya 10 oz. to 1 lb. of dry rubber per tree is obtained from 6-year old plantations; this increases gradually to 3 lbs. as the trees reach an age of 10 years. Higher yields are expected when the plantations are older. Older trees have actually yielded as much as 25 lbs. each, and in

PLATE XX.

RUBBER-TAPPING.



1. Full spiral (3 incisions).
2. Half spiral (3 incisions).
3. Full herring-bone.
4. Half herring-bone.

[To face page 196

Perak eight trees 17 years of age have yielded 28½ lbs. per tree.

As regards yield per acre, good plantations in Malaya are generally estimated to yield 100 lbs. of rubber per acre per annum at an age of 5 or 6 years, and at an age of 10 years they may be expected to give 3 or 4 times this amount.

Whether or not the plantations of India and Burma will give as high a yield remains to be seen.

7. *Preparation of Rubber.*

Solid rubber can be obtained by allowing the latex to dry naturally, but this method is not satisfactory, for besides the fact that it is liable to contain impurities, the latex is apt to putrefy if left standing, and hence special methods of preparing the rubber are necessary.

Centrifugalization, that is the separation of the rubber particles by means of a centrifugal machine, which is successful with *Castilloa* rubber, has been tried repeatedly for *Hevea* rubber, but without much success. *Coagulation* with special reagents therefore has to be employed. Coagulation by boiling, which is successsful for Ceara rubber, is not successful in the case of *Hevea* rubber. The latter, however, coagulates readily with the addition of even a small quantity of acid, and this is the method commonly employed in the East. Several acids have been tried, of which acetic acid has been found the most satisfactory, for although a larger quantity of it by weight is required to produce coagulation than in the case of other acids, there is a greater margin of safety if an excess is added, a very slight excess of some acids preventing coagulation. Certain salts have been tried for the coagulation of *Hevea* rubber, the most successful being mercuric chloride (corrosive sublimate), which however, has the disadvantage of being a very poisonous substance, though it has the advantage of preserving the rubber made with it. Rubber prepared with acetic acid will get mouldy and deteriorate if not kept dry ; creosote may be used as an antiseptic, but much of the plantation rubber is not cured with antiseptics, as it is prepared in thin sheets and dries rapidly. The method employed in the Amazon valley with natural *Hevea* rubber is to smoke it, the smoke containing small quantities of acetic acid and creosote. This method is advocated by some for the plantation rubber in the East

Various coagulating machines are in use, and for the subsequent preparation of rubber for the market washing and drying machines and rollers are employed. Various commercial forms of rubber are produced in the plantations of the East, the chief being (1) *Sheet* rubber, in large thin sheets, usually rectangular in shape, obtained by coagulation in shallow vessels and then rolling, (2) *Biscuits*, or thin flat cakes of circular shape, usually $\frac{1}{16}$ inch to $\frac{1}{8}$ inch thick and 10 inches to 14 inches in diameter, prepared in the same way as sheet rubber, (3) *Worms*, or thin worm-like pieces of unequal length, consisting of the parings of irregular sheets, (4) *Crêpe* rubber, very thin sheets with a crinkled appearance owing to the stretching and tearing they have undergone in the washing and rolling machines, (5) *Lace* rubber, long, very thin perforated sheets resembling lace, (6) *Block* rubber, which is pressed into solid blocks, and when properly manufactured commands a higher price on the market than any other form of rubber, (7) *Scrap* rubber, an inferior grade of rubber, consisting chiefly of pickings of coagulated latex from the tapping-wounds in the trees, and containing many impurities.

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CHAPTER X.

Drugs, Spices and Fish-Poisons.

SECTION I.—DRUGS AND SPICES.

There are so many drugs obtained from Indian plants that a complete enumeration of them would fill a large volume; a few examples must therefore suffice. Among medicinal barks may be mentioned those of *Soymida febrifuga*, used as a febrifuge and stimulant, *Careya arborea*, an astringent, *Holarrhena antidysenterica*, used in dysentery and as a tonic and febrifuge, *Myrica Nagi*, an aromatic stimulant, and *Cinchona* spp., which yield the well-known quinine and other similar alkaloids used for fever. The cinchonas are not indigenous in India, having been introduced from South America in 1860; they are, however, largely cultivated.

The "Cassia-bark" of commerce, an aromatic medicinal bark, is obtained from *Cinnamomum Tamala*, while *C. zeylanicum* yields the cinnamon bark so largely used as a spice. An extract from the bark and wood of several species of *Berberis* is used as a tonic and febrifuge.

The Aconites—*Aconitum* spp., chiefly *A. ferox*, order *Ranunculaceæ*—are herbaceous plants found in the Alpine and Sub-Alpine regions of the Himalayas; they yield important drugs and poisons. The Chireta—*Swertia Chirata*, *Gentianaceæ*—is a herbaceous plant of the Temperate Himalayas; the dried plant is used as a tonic and febrifuge. *Podophyllum Emodi*, a herbaceous plant with a perennial rhizome, growing at temperate elevations in the Himalayas and Kashmir, produces the valuable drug Podophyllin, a resin extracted from the rhizomes and roots. This drug was formerly obtained only from *Podophyllum peltatum*, an American species, but it has been found that the Indian species contains a larger proportion of resin than the American plant, so that there appears every chance of a profitable market being established for the Indian drug in places where it can be collected and extracted cheaply. *Kúth* or *Kúst* is the strongly-scented root of *Saussurea Lappa*, a tall herbaceous plant found in Kashmir, used as a stimulant and in skin diseases, also in perfumery, and to keep insects off clothes; large quantities are collected and exported from Kashmir. The roots are dug up in September and October, cut into pieces a few inches long, and exported either without any further preparation or after being dried in the smoke of a fire of green twigs.

Many leaves are used in medicine. The leaves of *Cassia angustifolia*, introduced from Arabia and cultivated in India, constitute the purgative drug senna. Those of *Melia indica* and a few others are used to keep insects off clothes. The leaves of *Melaleuca Leucadendron* yield the Cajuput oil of commerce, used internally as a stimulant and externally as an embrocation.

The aromatic leaves of *Cinnamomum Tamala* are known as *tejpat* and are commonly sold in bazaars for use as a spice and as a drug for dyspepsia and other complaints.

Many fruits and seeds yield valuable drugs. The seeds of *Butea frondosa* are used as a vermifuge for elephants and horses; those of *Cæsalpinia Bonducella* (the "fever-nut") are pounded and used as a tonic and febrifuge. The pulp of the pods of *Cassia Fistula* is a strong purgative, while *Tamarindus indica* supplies a laxative medicine from the pulp of its pods. The pulp of the fruits of *Ægle Marmelos* is used for dysentery and as a laxative. The seeds of the *Strychnos Nux-Vomica*, which yield the alkaloids strychnine and brucine, form an important article of trade. The fruit is a large orange-coloured berry containing a pulp in which the round, flat silvery seeds are embedded; to be commercially valuable, the seeds should be washed out of the pulp, and not picked up off the ground, when they lose their silvery appearance and are dull coloured.

The small red seeds of *Abrus precatorius*, well known as goldsmith's weights, contain a violent poison which is sometimes put to criminal use, particularly in the poisoning of cattle by hide-contractors. The seeds are ground down to a paste with a little cold water and made up into small pointed cylinders, which if inserted below the skin of a human being or of a grazing animal, cause death in a few hours. The poison is closely akin to that of snakes. Boiling destroys the poisonous property, and when well boiled the seeds may be eaten.

"Cardamoms" form an important article of trade. These are the capsules of two species of plants belonging to the order *Scitamineæ*, containing seeds which are used as an aromatic drug and as spice for flavouring purposes. The lesser or Malabar cardamom, which is the better kind, is furnished by *Elettaria Cardamomum*, a large perennial herb which sends up long flowering scapes, the fruit being ready for collection in October and November : this plant is found wild in the rich, moist forests of many parts of Southern India and Burma, and is also largely cultivated. The greater cardamom is yielded by *Amomum subulatum*, a native of Nepal : it is of less value than the lesser cardamom, and is employed as a cheap substitute for it.

The flower-heads of the herbaceous plant *Spilanthes Acmella* (order *Compositæ*), found throughout the greater part of India, are very acrid, and are used as a stimulant.

SECTION II.—FISH-POISONS.

Although fish-poisons are to be regarded as destructive agencies rather than as Economic products, it is important that the Forest Officer should have some knowledge regarding the principal sources of these poisons.

Among barks employed to poison fish may be mentioned those of *Ougeinia dalbergioides*, *Walsura piscidia*, *Mundulea suberosa*, *Flueggea microcarpa*, *Barringtonia acutangula*, *Berberis aristata*, *Myrica Nagi*, *Albizzia procera*, and several others.

The roots of *Millettia pachycarpa* and the chopped stems of certain species of *Euphorbia* are used as fish-poisons. Among fruits and seeds may be mentioned those of *Sapium indicum* (seeds), *Randia dumetorum* (fruit), *Gynocardia odorata* (fruit pulp), *Casearia graveolens* and *C. tomentosa* (fruit), *Mundulea suberosa* (seeds), *Diospyros montana* (fruit), *Barringtonia* spp. (seeds), *Hydnocarpus venenata*, and *H. Wightiana* (fruit). The flower-heads of the composite plant *Spilanthes Acmella*, referred to above, are often used for poisoning fish.

Under this head may be included *Antiaris toxicaria*, a large evergreen tree of Burma and the Western Ghats which exudes a white resin used as a poison for tipping arrows to kill game.

CHAPTER X.

Edible Products.

Section I.—Edible Flowers, Fruits and Seeds.

We cannot here consider the various cultivated fruit trees, as their fruits can hardly be included as forest produce in the usual sense of the word. Among forest trees and shrubs there are many which yield edible fruits and are often of great value in times of famine, for example those of *Dillenia pentagyna*, *Bassia latifolia*, *Berberis* spp., *Garcinia* spp., *Grewia* spp., *Citrus* spp., *Zizyphus Jujuba*, *Schleichera trijuga*, *Spondias mangifera*, *Rubus* spp., *Prunus* spp., *Pyrus* spp., *Diospyros* spp., *Carissa Carandas*, *C. macrophylla*, *Baccaurea sapida*, *Morus alba*, *Ficus* spp., *Eugenia Jambolana*, *Mimusops Elengi*, *M. hexandra*, *Ficus glomerata*, and many others. The seed of *Dendrocalamus strictus* is collected and eaten in time of famine; the collection is effected by shaking the bamboos when the seed is ripe and collecting it on cloths spread on the ground; the seed is then winnowed by hand to remove that which contains no grain. The fruits of *Ægle Marmelos* are used for making conserve; those of *Capparis horrida*, *Spondias mangifera* and *Phyllanthus Emblica* are pickled, while the fruits and flower-buds of *Capparis aphylla* are eaten, usually pickled. The large fleshy peduncles of the fruit of *Hovenia dulcis* are edible.

Among edible seeds may be mentioned those of *Pinus Gerardiana*, which grows in the North-West Himalayas and Afghanistan; the seeds are largely brought into India for sale from Afghanistan. The seeds of *Buchanania latifolia*, *Corylus Colurna*, *Indigofera glandulosa*, *Æsculus indica*, *Bauhinia Vahlii*, and the kernels of *Terminalia belerica*, are also eaten. *Anacardium occidentale* furnishes the well-known Cashew nuts; this tree was originally introduced from America, but has established itself in some of the coast forests of India; the kernels are separated from the fleshy peduncles to which they are attached, and are dried and roasted before use.

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Among edible flowers perhaps the most important are those yielded by *Bassia latifolia* (the *Mahwa* or *Mhowra*); the corollas of these flowers are eaten fresh or dried, ground, and mixed with flour for bread, or are distilled into *Mahwa* spirit, an intoxicating liquor. The flowers are collected as they fall on clean spaces swept on the ground under the trees, the collection taking place in the hot season: the flowers of *Bassia longifolia* are used in the same way in Southern India, those of *Rhododendron arboreum* are made into jam. The flowers of *Ougeinia dalbergioides* and the flower-buds of *Bauhinia variegata*, *Bombax malabaricum* and *Moringa pterygosperma* are eaten as vegetables.

SECTION II.—STARCHY PRODUCTS.

Starchy products are obtained from the inner soft tissue of the stems of certain palms and cycads such as *Caryota urens*, *Wallichia disticha*, *Phœnix acaulis*, *Borassus flabellifer*, *Corypha umbraculifera* (the Talipot palm), *Arenga saccharifera*, *Cycas Rumphii*, and *C. pectinata*. The soft starchy tissues are often cooked and eaten as they are, but the starch can easily be extracted by crushing the tissues and washing them well in water; the liquid is then passed through a sieve and the water allowed to evaporate, the starch remaining behind. The starchy tissues are sometimes dried and then ground to powder before being placed in the water.

There are many plants in India whose tubers or corms contain large quantities of starch and are used as articles of diet, for example *Dioscorea* spp. (Yams), *Pueraria tuberosa*, a leguminous climber with large tubers, *Curcuma angustifolia*, the East Indian arrowroot, several of the *Aroideœ* (*Amorphophallas*, *Colocasia*, *Nelumbium*, *Arum*, etc.), and many other plants. Many of these starchy tubers contain poisons which have to be extracted by soaking for 3 or 4 days in water, or by placing in running water for a couple of days, with subsequent boiling.

SECTION III.—SUGARY SAP.

Sugary sap is yielded by various species of palms, the chief of which are *Cocos nucifera* (the cocoanut-palm), *Borassus flabellifer* (the palmyra or toddy-palm), *Caryota urens* (the sago-palm), *Arenga saccharifera*, *Nipa fruticans*, and *Phœnix sylvestris* (the wild date-palm).

In all but the last of these the sap is obtained from the cut stalk of the inflorescence (spadix) before the flowers open, an earthen vessel being tied to the cut end of the stalk to receive the sap, which is emptied out as a rule twice a day. A thin slice is pared off the cut end of the stalk from time to time to renew the wound and cause a further flow of sap.

In the case of the cocoanut-palm and the sago-palm the spadix is first prepared for several days by beating, crushing, and cutting in order to induce the sap to flow, after which preliminary treatment the vessel is tied to the stalk; further twisting and crushing of the stalk is carried out at intervals throughout the season in the case of the sago-palm.

The sap of *Phœnix sylvestris* is obtained by cutting a notch in the soft wood at the base of the lowest living leaves, and a vessel is tied to the tree to catch the juice. The wound is renewed from time to time by paring off a thin slice, so that by the end of the season there is a large notch in the tree. In the following year the notch is cut on the opposite side; thus the tree in time gets a curious zig-zag appearance. The tapping season commences in October and ends in March.

The sap obtained from these palms is used for drinking, either fresh or after being fermented into an intoxicating liquor; vinegar is also made from the fermented sap, while the juice is largely employed for boiling down into raw sugar known as jaggery or gur, which is further refined into sugar.

SECTION IV.—FUNGI AND LICHENS.

Certain species of edible fungi are exported from the forests for trade, or are consumed locally. Large quantities of an edible fungus known as the morell (*Morchella esculenta*) are exported to the plains from Kashmir and elsewhere in the Himalayas; these are collected in April and strung up on a string to dry in the sun previous to export. There are also various edible fungi of less importance obtained from the forests.

Edible truffles, known in Burma as *kaing-u*, are obtained in the rainy season. From the roots of the *kaing* (elephant grass) while another form of edible truffle grows on the roots of *Pinus Khasya*.

In certain parts of Madras edible lichens, of the genus *Parmelia*, are collected during April and May.

CHAPTER XI.

Materials used for Basket-work and Matting.

SECTION I.—BASKET-WORK.

Baskets and basket-work articles are most largely made from canes and bamboos. Of the former the best known are (1) *Calamus tenuis*, the common rattan of Northern India, largely used for basket-work, chairs, screens, etc., (2) *C. Rotang*, the common rattan of Southern India, used for similar purposes, but is not very strong, (3) *C. acanthospathus*, (Syn. *C. montanus*), the best of the Eastern Himalayan rattans; somewhat thick, and used for chairs, cane-bridges, etc., (4) *C. latifolius*, a thick strong rattan of the Eastern Himalayas, used for similar purposes. There are several other canes or climbing palms used for basket-work, among the latter being certain species of *Dæmonorops* and *Plectocomia*, which, however, have somewhat soft stems, and are inferior to most of the true canes (*Calamus* spp.).

Many species of bamboos are used for basket-work, the first year's culms being preferred owing to their pliability.

Many dicotyledonous species are also employed, the chief requisites being pliability (for which reason green stems should be used), toughness, and a fair degree of rigidity after drying; of these species the twigs and coppice shoots are generally used. The following are among the more important dicotyledonous plants, the stems or twigs of which are used for basket-work:—

Acacia arabica, Alnus nitida, Butea frondosa, Dalbergia Sissoo, Grewia oppositifolia, Helicteres Isora, Indigogera atropurpurea, I. heterantha, Morus alba, Nyctanthes Arbor-tristis, Orthanthera viminea, Parrotia Jacquemontiana, Putranjiva Roxburghii, Rhus Cotinus, R. mysorensis, Salix spp., *Tamarix dioica, Tiliacora racemosa, Vitex Negundo, V. trifolia.*

The leaf-petioles of certain palms are used for basket-work, chiefly those of *Borassus flabellifer, Caryota urens, Nannorhops Ritchieana*, and *Phœnix sylvestris*.

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The use of grasses for basket-work and mats has been referred to on page 161.

SECTION II.—MATS.

Many species of bamboos are used for matting, among the principal being *Bambusa Tulda*, *B. pallida*, *B. arundinacea*, *Dendrocalamus strictus*, *Cephalostachyum pergracile* and *Melocanna bambusoides.*

Palm leaves form an important source of matting material, the leaves chiefly used being those of *Borassus flabellifer*, *Cocos nucifera*, *Corypha umbraculifera*, *Licuala peltata*, *Livistonia Jenkinsiana*, *Nannorhops Ritchieana*, *Phœnix sylvestris* and other date-palms.

Among other plants used are certain rushes (particularly *Juncus effusus*), sedges (*Cyperus* spp.), and canes, as well as the leaves of the screw-pine (*Pandanus odoratissimus*), the alœ (*Agave americana*) and the aquatic herbaceous plants *Typha angustifolia* and *T. elephantina*.

The "coir" mats so largely used are made of the fibre round the cocoanut fruit.

CHAPTER XII.

Minor Products used in the Manufacture of Paper.

Most fibres employed for rope-making and spinning can be used for paper manufacture. The bast-fibre of *Streblus asper* is used for the purpose in Siam, while that of *Broussonetia papyrifera*, the "paper mulberry," is extensively used in Japan and in the Shan States of Burma. The Nepal paper, employed in Northern India for deeds and other permanent records on account of its great durability, is made from the bast fibre of *Daphne cannabina*.

Of recent years special attention has been devoted to the question of utilizing bamboos and grasses for the manufacture of paper-pulp. Detailed experiments have revealed the fact that in bamboos of all kinds we have a most important and extensive source of supply of raw material for the manufacture of a good quality of pulp. Various grasses, some of which are very plentiful, have also been found to produce pulp of good quality; the chief of these are *Saccharum* of different species, *Ischœmum angustifolium* (*bhaber* grass), *Anthisteria gigantea* (*ulla* grass), a tall grass abundant on the open blanks in *sál* forests, and the *kaing* grass of Burma, embracing different species of tall coarse grasses, some of which cover extensive areas on alluvial flats near streams.

Details regarding the manufacture of paper pulp will be found on pages 281 to 287.

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CHAPTER XIII.

Miscellaneous Minor Products of Vegetable Origin.

In this chapter are included a number of miscellaneous minor products which cannot be conveniently classified under any of the main heads already dealt with.

SECTION I.—PRODUCTS FROM STEMS AND ROOTS.

The *sola* or pith used for manufacturing hats is obtained from the stems of *Æschynomene aspera*, a leguminous aquatic plant found in and around lakes and tanks throughout Bengal and in parts of Assam, Burma, Southern India and elsewhere. In Bengal and Assam there is a regular industry in pith working, the so-called pith which is in reality soft white pith-like wood, being obtained from the thicker portions of the stems. The stems are cut into lengths of 2 or 3 feet and dried, the bark being then removed, leaving the so-called pith, which for the manufacture of hats is slit into thin sheets. A harder and inferior grade of pith is obtained from *Æschynomene indica*, which is less aquatic in its habits and is often found above water-level. The so-called pith of this plant is largely used for the manufacture of *sola topees*, a surface-dressing of Bengal pith being added ; it is also used for making artificial flowers.

"Barilla" is carbonate of soda obtained from the ashes of certain saline plants of Sind, the Punjab, and elsewhere, of the order *Chenopodiaceæ* (*Suæda*, *Salsola*, *Haloxylon* and other genera) ; the same substance is obtained from the efflorescence in the soil, known as *reh*, found in many parts of India. In the Punjab barilla is prepared by cutting the plants when in flower, drying them, and burning them over a basin-shaped hollow in the ground ; in burning the plant gives out a liquid substance which settles in the bottom of the pit and is stirred up with the living coals and ash ; the glowing mass is then covered with earth until it cools, and after three or four days is re-opened, when a quantity of barilla is found at the bottom of the pit.

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"Pearl-ash" is quite a different substance, a form of potassium carbonate obtained from the ashes of a large number of plants of no particular genus.

The bark of *Acacia leucophlœa* is used to clarify the toddy of the palmyra palm through the precipitation, by means of its tannin, of the albumen in the palm juice; that of *Grewia asiatica* is used for clarifying sugar. The bark of *Betula utilis* is employed as writing paper and for packing, umbrellas, roofing houses, and other purposes.

Slow-matches, or fuses, are made from the barks of *Careya arborea, Bauhinia racemosa, Cordia Myxa, Butea frondosa* (root-bark), *Ulmus Wallichiana,* and other species.

SECTION II.—LEAVES.

Leaves most largely used for thatching are those of several species of palm, for example *Nipa fruticans, Pinanga gracilis, Licuala peltata, Livistonia Jenkinsiana, Borassus flabellifer, Cocos nucifera, Wallichia* spp., and others. Many other broad kinds of leaves are also employed, such as those of teak, *Bauhinia Vahlii, Dillenia pentagyna, Pterospermum acerifolium, Butea frondosa,* etc. These leaves are often used in conjunction with grass thatch: before use they should be pressed flat in bundles and partially dried.

Certain large leaves, such as those of teak, *Bauhinia Vahlii,* and *Butea frondosa,* are used for umbrellas, cups and plates.

Cheroot-wrappers are made out of various kinds of leaves, the species most commonly used being *Cordia Myxa* (Burma), *Diospyros tomentosa* (Central Provinces and Bombay), *Careya arborea* (Burma), *Bauhinia racemosa, B. variegata,* and *Shorea robusta* (used by the Santals).

Certain rough leaves are used to polish wood, ivory, and horn, for example those of *Streblus asper, Trema politoria, Ficus gibbosa, F. asperrima, F. Cunia, Delima sarmentosa, Dillenia indica,* and *Nyctanthes Arbor-tristis.*

SECTION III.—FRUITS AND SEEDS.

The fruits of *Sapindus emarginatus* (the "soapnut" fruit) are largely used as a substitute for soap; other soap-substitutes are the pods of *Acacia concinna* and *A. Intsia,* and the pulp of the fruit of *Balanites Roxburghii.*

The fruit of *Diospyros Embryopteris* contains a viscid pulp used as gum in book-binding, and as a substitute for tar for paying the seams of boats. *Semecarpus Anacardium* is known as the marking-nut tree, because in its fruit is a corrosive juice which is used as marking Ink.

Among cucurbitaceous fruits may be mentioned the well-known bottle-gourd (*Lagenaria vulgaris*) used for holding water, and the fruit of *Luffa acutangula*, the fibrous portion of which, after the pulp has been removed, is used as a flesh-brush.

The small hard red seeds of the common climber *Abrus precatorius* are used as goldsmiths' weights : the large brown seeds of the climber *Entada scandens* are hollowed out and made into snuff-boxes. The flat winged seeds of *Oroxylum indicum* are used for lining hats and, placed between two layers of wicker-work, for covering umbrellas.

Many kinds of hard, and often ornamental, seeds are used as beads, holes being drilled through them to enable them to be strung together. The best examples are the small bright red seeds of *Abrus precatorius* (*rati* or crab's-eyes), the scarlet seeds of *Adenanthera pavonina*, somewhat similar to but larger than those of *Abrus*, and without its black spot, the greenish-grey seeds of *Cæsalpinia Bonducella*, the "fever-nut," the round black seeds of the Canna (*Canna indica*), known as "Indian shot," the grains of the grass *Coix lachryma* or "Job's tears," which grows in marshy ground, the nuts of the palm *Corypha umbraculifera*, worn as beads by Hindu devotees, the grooved nuts of the *Rudraksha* (*Elæocarpus Ganitrus*), worn as necklaces by followers of Shiva, the large seeds of the climber *Entada scandens*, used for making bead-chicks, the stones of the fleshy fruit of *Melia indica*, the *Nim* or bead-tree, worn as a charm against infection from small-pox and other diseases, and the hard nuts of *Putranjiva Roxburghii*, worn as rosaries to avert the evil eye.

Several of these seeds are used in the "seed and bead industry," a Missionary enterprise of Bombay which turns out very ornamental articles from seeds, either alone or in conjunction with beads, the articles manufactured being necklaces, ladies' hat-pins, bead-chicks, etc. For the hat-pins the seeds most commonly employed are those of *Cæsalpinia Bonducella*, *Elæocarpus Ganitrus* and *Martynia diandra*. The last named plant was originally introduced from America, but has become naturalized in India. The seeds have a pair of sharp hard curved claws, and are made to imitate beetles, a pair of bright beads being inserted as eyes.

CHAPTER XIV.

Animal Products, including Hunting, Fishing and Elephant-catching.

The most important animal products with which Forestry is directly or indirectly concerned in India are (1) lac, (2) silk, (3) honey and wax, (4) hides, horns, bones, and ivory, and (5) certain miscellaneous products. Under the head of animal products may also be included hunting, fishing and elephant-catching.

SECTION I.—LAC.

1. *General Account.*

Lac is a resinous incrustation on the twigs of various trees produced by a minute Hemipterous insect called *Tachardia Lacca*, Kerr, (syn. *Coccus Lacca*) of the family *Coccidæ*. It is quite probable, however, that some of the lac ascribed to this species is in reality produced by other species. It is known that lac is also produced by *T. fici*, Gr. and *T. albizziæ*, Gr., but it is not yet clear how many species actually produce lac, or even if *T. Lacca* is the chief lac-producing species. This resinous substance contains a crimson dye known as lac dye, which was formerly of great value, but has been almost entirely driven out of the market since the introduction of aniline dyes. The resinous substance known commercially as shellac is, however, of great commercial value, being used in the manufacture of varnishes, cements, sealing wax, lacquer work, lithographic ink, gramophone records, and many other purposes.

The lac insect feeds on the juicy twigs of various species of trees. The best lac is produced on *Schleichera trijuga*, but there are many other good lac-producing trees, notably *Butea frondosa*, *Zizyphus Jujuba*, *Shorea Talura*, *Ficus* spp., *Acacia arabica*, and many others.

The lac insect has many enemies. The caterpillars of certain moths eat the lac larvæ, while monkeys and birds also damage the lac. Ants are often found in numbers on the lac, but there is considerable difference of opinion as to the amount of damage they do. Heavy rain is very destructive, particularly at swarming times, when large numbers of larvæ are washed away; jungle fires also do great damage.

2. *Life History of the Lac Insect.*

The minute larvæ of the lac insect generally swarm at two seasons of the year. The actual time varies considerably in different localities; as a rule one swarming takes place early in the rainy season and the other early in the cold weather. The swarming continues as a rule for about 10 days to a fortnight, sometimes longer; during this time the twigs become reddish in colour with the large numbers of minute larvæ with which they are covered. The females, which have hatched out these larvæ within the resinous mass, die as soon as the larvæ have hatched, or may be said to be mere shells full of larvæ even before the latter swarm out. On swarming out the larvæ quickly spread over the twigs and feed on them by sucking out the juice, meanwhile covering themselves with a resinous incrustation; when the males become mature they in turn swarm out and impregnate the females, which remain in cells within the resinous mass and bring forth the next brood of larvæ, the same process being repeated cycle after cycle. The males die after impregnating the females. The swarming of the perfect males takes place about 2½ months after the swarming of the larvæ; the males of the first brood are wingless and those of the second brood have one pair of long transparent wings. In some localities there are three broods in the year; in this case it is quite possible that the species is not the same as the two brood species.

3. *Propagation of Lac.*

To propagate lac pieces of *brood-lac* about 6 to 12 inches long are tied up in the upper parts of the trees, surrounded with straw to protect them from the weather; this brood-lac, or *seed-lac* as it is sometimes called, is merely lac from which the larvæ have not yet swarmed. In wet weather, it is believed that the straw does more harm than good, as it makes the brood-lac too damp. The brood-lac should not be cut off the parent tree until it is nearly time for the larvæ to swarm, otherwise the loss of sap from the twig will result in the death of the female, and no larvæ will be produced. For this purpose the actual dates of swarming in each locality should be noted and recorded, as they are more or less the same in each year. Care should be taken not to tie the brood-lac tightly round with string, as this is apt to destroy many larvæ. The twigs of the tree to which the brood-lac is transferred should not be harder than those of the parent tree, otherwise the larvæ may not have strength to feed on their new host. The lac can best be grown on pollarded trees, as these produce more juicy twigs. When lac is once established on a tree in order to maintain a permanent supply, a common practice is to leave a few branches with lac on them at the time the cutting of lac-covered branches for the market is carried out. It is probable, however, that higher yields will be obtainable by complete pollarding, the trees being worked in rotation and the new crop being produced entirely from bundles of brood-lac tied up at each swarming time. Experiments in this direction are in progress at the Forest Research Institute.

4. *Collection of Lac.*

If the desire is to preserve the lac dye, which is contained in the larvæ, the lac should be collected before the larvæ swarm out, that is, normally in May and June and in October and November. As lac dye now has little value there seems to be no reason why the lac should not be collected for the market after the larvæ swarm, as this would facilitate the spread of the lac naturally and would also make the process of preparing shellac easier. The habit, however, of collecting the lac while the larvæ are still in it is generally adhered to. The principal reason for this is that the time during which the lac while on the tree has to be guarded day and night from theft is shortened. The lac is collected by cutting off the twigs which are encrusted with the lac; in this unprepared condition it is termed *stick-lac*.

5. *Preparation of Lac Dye.*

The stick-lac on being brought in from the forest is broken into short pieces and crushed to loosen the lac from the pieces of twigs, the lac being then separated from the wood, bark, and other useless material; in this state the lac is commercially called seed-lac, though, as already stated, this term is also used for brood-lac. This lac is placed in water in a stone trough or tub for 24 hours, after which it is pressed and ground against the rough surface of the trough by a twisting motion of the feet of a person standing in the trough; this washes out the dye from the lac, the water becoming dark crimson in colour. By means of two or three changes of water all the dye is thus extracted from the lac; the liquid is strained and the dye is allowed to settle, precipitation being aided by the addition of lime or alum. The water is then drawn off and the sediment is pressed into cakes and dried.

6. *Preparation of Shellac.*

The lac, from which the dye has been extracted, is packed in long narrow cloth bags, which are then held in front of charcoal or coke fires specially constructed to throw the heat out in front; one man holds one end of the bag and another the other end, each twisting in opposite directions, with the result that the lac, which is melted with the heat, drips through the cloth on to plantain stems or polished tiles placed below. The next part of the process is to stretch the shellac into fine sheets like paper. This is done by squeezing the molten lac out along a plantain stem or a porcelain tube filled with hot water; this sheet of lac is then trimmed at each end, held fairly near the fire and stretched to fully double the size, after which it is laid on a mat and carried further and further away from the fire to allow it to cool slowly. These thin sheets of lac are known as *shellac;* defective parts are broken out of them, and all the fragments of shellac are sorted into different qualities for the market. Only the finer qualities of seed-lac are made into shellac. *Button-lac* is produced by allowing the lac squeezed from the melting-bag to fall on a smooth surface into circular pieces about an inch and a half in diameter.

For certain classes of shellac it is necessary to mix the lac before it is put into the melting-bag, with orpiment (yellow arsenic) or rosin, or both; the former makes the shellac opaque and gives it a pale yellow colour characteristic of some of the better qualities of shellac, while the latter, which should not exceed 2 to 5 per cent., serves to lower the melting-point of the shellac, a property required in certain industries. Rosin being cheaper than lac, care is necessary to guard against the mixture of an excess of rosin in the

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shellac. No admixture of rosin or arsenic is required for the preparation of button-lac.

A trade form of lac which has recently come into prominence is *Silk-lac,* produced in silk-like threds from alcoholic extract. This is considered the best form of lac, as it does not block or lose its solubility in alcohol after long storage.

SECTION II.—SILK.

Silk is the fibrous substance obtained from the cocoons of various moths, the larvæ of which are popularly known as silkworms: to obtain the silk the cocoons are placed in hot water and the threads of silk are reeled off. Commercially speaking silkworms are divided into two great divisions, the *domesticated* or *mulberry-feeding* and the *wild* or *non-mulberry-feeding* silkworms: this distinction, though convenient, is not strictly correct, as many of the so-called wild silkworms have been domesticated, while some may feed on mulberry leaves.

The *domesticated* silkworms include various kinds of *Bombyx,* by some regarded as mere varieties of one species *Bombyx Mori*; these are, however, commonly designated by separate specific names. These silkworms comprise the domesticated *Bombyces* which are reared in Bengal, Assam, the United Provinces, the Punjab, Kashmir, Burma, and elsewhere, as well as in China, Japan, and Southern Europe. They are fed on mulberry leaves, the trees being grown as pollards or coppice: in India there are two principal species of mulberry grown for this purpose, *Morus alba* in the Punjab and Kashmir, and *M. indica* in Bengal, Assam, Burma, the United Provinces, and parts of the Punjab.

The *wild* silkworms, which are often partly domesticated, belong to several genera, *Actias*, *Antheræa*, *Attacus*, *Cricula*, and a few others: some of these silkworms are reared in Bombay, Madras, and other parts of India where the mulberry-feeding kinds cannot be reared. The best known of the wild silkworms are the *Tasar* (*Antheræa Paphia*), the *Muga* (*Antheræa Assama*), and the *Eri* (*Attacus Ricini*). The original home of the *Tasar* silkworm is believed to be the northern part of the Peninsula, comprising part of the Central Provinces and Chota Nagpur; it extends occasionally to the foot of the Himalayas and into Assam and Madras. It is essentially a forest insect, feeding on the leaves of a large variety of trees, among which are *Bombax malabaricum*,

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Eugenia Jambolana, *Ficus* spp., *Shorea robusta*, *Terminalia* spp., and others. The *Muga* silkworm is a native of Eastern Bengal and Assam, extending into the north of Burma; its chief foods are *Machilus odoratissima*, *Litsœa* spp., and a few others. The *Eri* silkworm is met with chiefly in Assam, where its principal food is the castor-oil plant, *Ricinus communis.*

SECTION III.—HONEY AND WAX.

Honey and wax, produced by many different species of bees, form an extensive item of minor produce in several parts of India, particularly where large trees and rocks abound, where the bees can find suitable places for building their hives. Two of the commonest honey-bees in India are *Apis dorsata* and *A. indica.* The former, which builds large combs, is found all over India and Burma, but does not extend high into the hills; its domestication has been attempted, but without success. *Apis indica* is a smaller bee, more nearly allied to the European honey-bee (*A mellifica*); this bee, which is also found throughout India and Burma, builds small combs, which in the plains do not yield much honey, but in the hills, where the bee has been domesticated and is artificially reared, considerable supplies of honey are obtained. Some of small dammar-bees (*Melipona* spp.), chiefly characteristic of Burma, in addition to producing the dark resinous substance known as "dammar," also furnish a good quality of honey.

There are various ways of collecting the honey, the commonest, in the case of dangerous bees, being for the collector to cover himself with a blanket and ascend the tree, driving the bees out with a lighted torch and then collecting the combs in a basket and lowering them down to the ground by a long rope: this is often done at night for greater safety. In the case of the less dangerous bees such precautions are not necessary, the bees being driven off merely by shaking the branch on which they have built their comb. Among some jungle tribes the honey collectors are said to smear their bodies with a substance which renders them immune from the attacks of the bees. Two crops of honey are often taken from the large bees (*Apis dorsata*), the first at the beginning of the rains and the second soon after their close; the first crop is said to produce a better quality of honey than the second. As much as 60 to 80 lbs. of honey are obtained from some of the large combs.

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The honey is separated from the wax either by shaving off the outer layers of the comb and letting the honey drip out of its own accord through a sieve or a piece of muslin, or else by squeezing out the honey through a cloth. Where bees are artificially reared the honey may be extracted by a centrifugal machine which leaves the empty comb intact: the comb is then replaced in the hive to be re-filled, the same comb often serving over and over again for a long time. The common method of obtaining the wax in India is to place the comb, from which the honey has been extracted, in boiling water; the wax then melts and floats to the surface, from which it is skimmed. Wax is used for making candles, polishing wooden floors, in the manufacture of sealing wax, and for many other purposes.

SECTION IV.—HIDES, HORNS, BONES, AND IVORY.

There is a large trade in hides in India, which has increased with the development of the tanning industry in different parts of the country. The trade in hides is chiefly in the hands of Mahomedans, as Hindus refuse to deal in them owing to religious scruples. The actual collection of skins is carried out by chamars, one of the lowest classes, who go about skinning the carcases of the numerous animals which die in the rural and grazing districts. These chamars are often professional cattle-poisoners, and therefore care is necessary, in leasing out any forest-grazing area to the collection of hides, to see that poisoning is strictly prevented.

The trade in horns is principally an export one, the chief uses of horn being for the manufacture of combs, buttons, drinking cups, and other minor articles. True horn is formed by the modification of the superficial layers of the skin, and is found as a covering to processes of bone in the case of the horns of cattle, goats, sheep, antelopes, and similar animals. The antlers of deer consist of bone, and have no true horny matter; these are normally shed every year, and may be collected off the ground, there being a trade in them for the manufacture of the handles of knives, sticks, and umbrellas and for various small fancy articles. If the collection of horns or antlers is permitted care is necessary to prevent the killing of animals for the purpose of obtaining them.

The trade in ivory, obtained from the tusks of elephants is small in India, the bulk of the world's supply of ivory being

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collected in Africa, where the excessive slaughter of elephants in past years has considerably reduced their numbers.

There is a large export trade in bones, which are collected in many parts of India and shipped to Europe, chiefly in the form of bone meal for manure. Bone is also used for the manufacture of knife-handles, buttons, and other small articles. Camel-bone is used in the Punjab for inlaying woodwork (picture-frames, etc.), as a substitute for ivory.

SECTION V.—MISCELLANEOUS ANIMAL PRODUCTS.

Under this head may be included manna or honey-dew, a sweet substance excreted on the leaves and twigs of trees by certain *aphidæ*; the trees frequented are chiefly gregarious conifers and some broad-leaved species. The sweet substance, which is especially plentiful in dry years, is washed off the twigs and leaves with hot water, the liquid being then boiled down to the consistency of honey, which it resembles. The hill people of the Himalayas collect honey-dew for their own use; as an article of trade it is of no importance.

Shells form an article of minor forest produce in the Sunderbans; these are employed for burning into lime, much of the finer quality of lime used in betel-chewing being obtained from this source.

Bats'-guano is collected from rocky caves. In Burma its principal use appears to be for the manufacture of saltpetre. The right of collection for the year is usually sold to the highest bidder. In Madras it is used as a manure for melons.

Edible birds'-nests are found in the Andaman and Nicobar Islands, Burma (south Tenasserim), and in one or two localities on the Bombay coast. These nests, which are largely composed of a gelatinous substance formed by the salivary glands of the birds, are made by certain species of swiftlet (*Collocalia* spp.), and are much prized by the Chinese as an article of food.

SECTION VI.—HUNTING AND FISHING.

1. *Hunting.*

The restriction of unauthorized hunting, which if carried to excess would mean the rapid extinction of game forms an

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important part of a Forest officer's duties. The measures to be taken to effect this purpose must naturally differ greatly according to locality, the regulations being stricter in places where shooting is much indulged in than in remote places where the game is more or less unmolested.

The following are the more important points to be considered in the regulation of hunting :—(1) the establishment of a close time for game, whether birds or mammals, during the breeding season; the possession of dead game at such seasons should also be made penal: (2) the formation of sanctuaries, where no hunting is to be permitted; these should not, however, be formed in the neighbourhood of cultivation: (3) the division of the forest into shooting blocks, in each of which only one party is allowed to shoot at a time, and in which only a specified number of head of game may be killed by each party: (4) the issue of shooting licenses on payment of fees; these licenses should have written on them all necessary conditions as to locality, date, number and species of game which may be killed, and other provisos: (5) the killing of females and immature males should be prohibited: (6) no trapping or poisoning should be allowed: (7) special measures may have to be taken in the interests of fire-protection, such as the closing of the forests during the fire-season and the enforcement of rules prohibiting the employment of inflammable wads: (8) camping should be allowed only in certain specified places, in order to facilitate supervision.

Special measures may have to be taken for the destruction of game for the protection of field crops; special provision is also necessary for the destruction of dangerous carnivora where these abound. In some parts of Europe a certain number of female deer are killed annually to maintain a normal proportion of males and females. This system would be difficult to apply in the majority of Indian forests owing to their extent and to the difficulty of supervising any such measure.

2. *Fishing.*

Forest streams are of greater importance than would at first sight appear, as they form the natural spawning grounds of the fish which supply the fisheries in the larger rivers, the fish seeking the shade of the trees and the quiet of the jungle streams for the purpose of depositing their spawn. Many destructive methods of killing fish in a wholesale manner are practised, such as damming up the streams and scooping out all the water, trapping without discrimination as to size of fish caught, poisoning or dynamiting the water, wholesale slaughter at night with the aid of torches, and other methods.

The principal measures which may be taken to regulate fishing and prevent the indiscriminate killing of fish are (1) the issue of permits or granting of leases on payment: (2) the prohibition of poisoning, dynamiting, or capture of fish of all sizes in a wholesale manner : (3) the fixing of a minimum size of mesh for nets or traps used for catching fish : (4) the maintenance of shade along streams by prohibiting the felling of trees along their banks : (5) the establishment of a close time for fish during the spawning season : (6) the destruction of otters, which kill large numbers of fish, should be encouraged by the offer of rewards, or by trapping or shooting.

SECTION VII.—ELEPHANT-CATCHING.

The capture of wild elephants for the purpose of training them to work in captivity is carried on in many of the forest tracts of India, and a work on Forest Utilization for India could hardly be considered complete without a brief account of the principal methods employed in their capture. Wild elephants commonly go about in herds, which vary in numbers. Where fodder is plentiful herds of 30 to 50 are usually found, but herds of 100 or more are not uncommon. Where fodder is scarce they divide into smaller parties of from 10 to 20. Males are often found in a solitary state, either because of their own preference for a solitary life or because they have been driven out by the rest of the herd or by males more powerful than themselves.

The principal methods of catching wild elephants are (1) in pit-falls, (2) by noosing from the backs of trained elephants, (3) by tying the legs together under cover of female decoys, (4) by noosing the hind legs on foot, (5) by enclosing in a palisade erected round a salt-lick or pool of water, (6) by keddahs. By the first four methods elephants are caught singly, while by the last two whole herds may be caught. The following is a brief description of each of these methods :—

(1) *Pit-falls.*—Rectangular pits with sloping sides, 10 to 12 feet deep and of dimensions usually 12′×12′ at the surface sloping to 9′×9′ at the bottom are dug in groups of two

to four (usually three) at convenient places throughout the ground frequented by the elephants, care being taken to remove the earth to some distance to avoid creating suspicion. These pits are filled for 4 or 5 feet with small brushwood covered with bundles of grass, and the top is covered over with a light platfrom of split bamboos, over which grass and dead leaves are strewn in such a way that the covering looks like the surrounding ground. The pits must be visited every day, and when a fall is discovered the captured elephant should be removed without delay: this is done by fixing a rope round the elephant's neck and throwing billets of wood into the hole until the animal can scramble out. The elephant is finally secured with more ropes and marched off with the help of trained elephants. Unless carried out properly this system is apt to be a very cruel one. Where pits are dug too deep or are not sufficiently filled with grass and brushwood to break the elephant's fall, the animal may be severely injured or even killed: again, if the pits are not visited daily the chances are that any hapless animal that may fall into a pit will die of starvation. In the Madras Presidency elephants captured in pit-falls are kept in "kraals" or large strongly built wooden cages, until they are reasonably tame.

(2) *Noosing from the backs of trained elephants.*—Under this system wild elephants are chased by trained animals urged to a rapid pace by repeated blows delivered near the root of the tail by men seated on their backs. On the wild elephant being overtaken, it is surrounded, noosed and securely bound: small elephants may be captured without difficulty, but in the case of large powerful animals it is often necessary to employ trained fighting tuskers to charge them again and again until they are somewhat subdued. This method is employed in Nothern India, having been originally introduced from Nepal. It is usual to begin the day by posting in suitable places a number of men armed with muskets and blank cartridges, the elephants being beaten out to where the trained elephants are kept in wait for them. This is one of the most exciting forms of elephant capturing, and is naturally by no means free from danger.

(3) *Tying the legs together under cover of female decoys.*—This is a method sometimes employed to capture solitary males. Four or five steady female elephants, ridden by mahouts who crouch down on their necks and cover themselves with dark-coloured blankets, are taken to the jungle

where the solitary male feeds, and are allowed to graze as if wild; they remain near him sometimes for two days and nights. As soon as the male falls asleep, usually soon after sunrise, the females stand round him and two mahouts get down and tie his hind legs together; in a day or two he can be captured without difficulty, as he soon exhausts himself in his efforts to run away with his legs fettered. If there is a convenient tree near, the end of the rope may be tied to it at the time the ropes are put round his legs.

(4) *Noosing the hind legs on foot.*—This is a method sometimes followed in Ceylon, where several hunters on foot with great skill noose the hind legs of an elephant running away, the trailing ends of the ropes being secured to trees as it passes. This method requires great dexterity, and can hardly be followed in general practice.

(5) *Enclosing in a palisade erected round a salt-lick or pool of water.*—This consists in building round a salt-lick or water-hole frequented by elephants a stockade with a gap for an entrance. The place is constantly watched by a number of men in concealment, and as soon as a herd enters the entrance is closed: the elephants are afterwards captured singly with the assistance of trained elephants and marched off. This method was formerly common in Assam, where great cruelty was practised owing to the hunters often leaving the unfortunate animals to starve to death when the number of tame elephants was insufficient to deal with a large herd of wild ones. Such waste of elephant life is no longer permitted.

(6) *Keddahs.*—This is the most certain plan for catching herds of elephants on a large scale; it consists in surrounding a herd by a large circle of men and driving it into a stockade previously built. Men to the number of 300 or 400 are collected and supplied with muskets and rations, the exact number of men depending on the area to be operated over; these move noiselessly in line through the jungle so as to take up positions about 30 yards apart in such a way as to form a long line completely encircling the place where the herd of elephants is known to be. This cordon of men is often 5 or 6 miles in length, and it may take 3 or 4 hours to complete the circle. When the cordon is completed the men run up a thin fence of split bamboos round the enclosure and clear a path from man to man. At night fires are lit, and if the elephants approach they are driven back by

shouting and firing of muskets ; the men camp at their posts often for a week, and sometimes for a whole month.

The elephants are most active at night, giving little trouble in the day-time as a rule. When the circle is completed the keddah is built ; this is a strong stockade 12 feet high, built of poles in a circle 20 to 60 yards across, a trench 6 feet wide and 4 feet deep being dug inside the stockade and the earth thrown up to the inside, this preventing effective attacks on the stockade from the inside. An entrance 4 yards wide is left for the herd to enter, a strong gate being constructed and studded with sharp spikes on the inside. From the entrance to the keddah two lines of strong palisades run out for about 100 yards, being 60 yards wide at the entrance ; these wings are meant to act as guides to force the elephants into the stockade. When the keddah and wings are completed some of the men from the outer cordon leave it and form a smaller circle inside, beginning at the wings of the keddah and taking up their positions so as to surround the herd ; the herd is then gradually driven forward towards the stockade. If they refuse to enter the stockade in spite of shots and shouts a new stockade may have to be built in another part of the enclosure, and the same process gone through again.

When once in the wings, the elephants are driven forward by firing a line of dry grass previously placed at the entrance to the wings; trained elephants are also employed to drive them into the stockade. When the herd has entered the stockade the gate is closed, and on the same or the following day tame elephants with mahouts on their backs enter and separate the wild elephants one by one, when men slip down and tie their hind legs; ropes are then fixed round their necks and hind legs and they are marched out and picketed in the forest near. Where experienced men are employed the danger involved by this method is not so great as might appear; accidents, however, are bound to occur from time to time. The Chittagonians are particularly skilful in this method of capture.

CHAPTER XV.

Mineral Products.

Among mineral products of the forest may be mentioned building-stones, road metal, clay, slate, limestone for burning, mica, laterite, sand, and other similar materials. These may be collected by (1) mining, that is, sinking a shaft below the surface and excavating underground, (2) quarrying, that is, making an excavation open to the air, (3) collecting off land covered with tree-growth, and (4) collecting from beds of streams. Mining affects the forest in that a considerable amount of débris is thrown up at the entrance to the mine; it is resorted to when the mineral-bearing strata run underground. Quarrying does much damage to the forest, especially on a hill-side, as it exposes the ground to landslips and causes damage to the forest beneath through the rolling down of stones and earth: on level ground the damage done consists in the reduction of the forest area. Collecting stones or other mineral products from forest land does much damage, as carts or pack animals are driven over the area, crushing young growth and, in the case of carts, damaging trees in passing. Collecting from beds of streams does no damage.

Revenue from mineral products may be obtained either by leasing on fixed payment or leasing and charging royalty on the outturn by weight, volume, or market value. Where limestone is collected from the forest and burnt in its neighbourhood it is convenient to charge for the fuel used by finding the average volume of fuel required for each burning of the kiln and levying the total price of the fuel according to the number of times the kiln is fired.

Mica mines are situated in Government forests in certain parts of Bengal and Madras, the mineral being quarried or mined according to whether its position is near the surface or some distance down. The value of the mica extracted depends on the size and clearness of the sheets, which are cut and sorted for the market according to size and quality.

In the Nellore District, Madras, duty is levied by royalties on the quantity of mica exploited. In the Palamau Forest Division of Bengal the mica-bearing area is demarcated into

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40-acre squares, each of which is leased for 30 years: the lessee pays a rent of Rs. 40 per square per annum or else 5 per cent. of the sale value of the outturn of mica, whichever is greater.

Calcareous tufa has been extensively quarried in the Haldwani Forest Division of the United Provinces, but since the discovery of tufa in a more accessible place at Lachiwala near Dehra Dun the outturn from Haldwani has dropped considerably.

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PART III.

ORGANIZATION OF LABOUR, AND MODES OF SALE AND DISPOSAL OF WOOD AND OTHER FOREST PRODUCE.

The whole subject of Forest Utilization in its practical application depends intimately on the methods employed in collecting and disposing of the various articles of forest produce, for it is one of the chief duties of the forester so to arrange for the collection and disposal of the produce from the forests under his charge that these forests may yield the highest possible income compatible with the maintenance and improvement of the forest, the interests of the neighbouring population being duly safeguarded. It is therefore necessary that some general knowledge should be acquired of the principles involved in the questions of forest labour and the various methods of disposing of forest produce. These questions may be conveniently considered under the heads of (1) the organization of forest labour, (2) methods of sale, and (3) system of extraction and disposal of forest produce.

CHAPTER I.

The Organization of Forest Labour.

SECTION I.—GENERAL.

India being a large country, in which local conditions vary much from place to place, the question of labour supply, which may present no difficulties in some localities, is in others a matter of serious difficulty where forest work has to be carried out.

Provided they are reasonably industrious, the people of the various jungle tribes make the most satisfactory forest workmen, as they become skilled in woodcraft and in the use of axes or other implements from childhood, while they are more inured to the climate and hardships of the jungle than men brought in from outside; the labour supplied by such tribes is, however, not always to be relied on, owing to the indolence often born of a life of freedom in people whose wants are few. The forester who can at all times command the labour of such jungle tribes for forest work has seldom cause to be dissatisfied. In Europe, particularly in Germany, permanent gangs of woodcutters are often to be found working continuously in one particular tract of forest from year to year, and earning their sole livelihood by cutting and converting wood; in some cases they are even kept together by subscription to a benevolent fund in aid of the aged and infirm, or of widows and orphans, such funds being supported by the woodcutters themselves. Such an advanced state of affairs is perhaps hardly applicable to India, but even in India permanent gangs of woodmen, whose sole occupation is cutting and converting wood, exist in many parts; in such cases labour can be depended on at short notice for the extinction of fires or for forest work in general. For the maintenance of such permanent labour it is necessary that regular work should be supplied throughout the year.

The necessity for maintaining a supply of purely forest labourers is not so great in India as in Europe owing to the

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fact that in India there is a much larger agricultural population, so that the people are naturally familiar with the use of the axe and other implements. In agricultural districts labour for forest work can generally be depended on at seasons when important field-work, such as ploughing, sowing, or reaping, are not in progress: the seasons for carrying out forest operations must, in fact, in some localities largely depend on the seasons of agricultural work.

The supply of forest labour as a rule varies in inverse ratio to the prosperity of the surrounding community, provided the population is normal. Thus where agriculture is in a precarious condition, and the people are therefore poor, forest work is sought after as a means of livelihood; in fertile localities, however, even though they may be more densely stocked, forest labour may be very difficult to obtain owing to the fact that the people are well off without having to seek for further employment.

Where labour cannot be obtained locally there is no alternative but to import it; this means increased cost owing to the journeys to and fro, and often higher wages as compensation to the workmen for leaving their homes. In India sawyers are not so readily obtainable as axemen, and often have to be obtained from a distance, the sawyers being largely confined to one particular class.

In order to ensure satisfactory work it is necessary to impose certain conditions, which would include, among other matters, avoidance of damage to the forest, camping and lighting fires only in certain specified places, assistance in case of fire, and abstinence from the commission of forest offences. Where labour is not directly supervised by an official it is usually advisable to appoint one specially selected man as foreman, who should receive higher wages than the remainder of the workmen.

Among special forms of labour may be mentioned the convict labour employed in the Andamans, this labour being classified into various grades according to severity.

SECTION II.—WAGES.

Wages for miscellaneous forest work are usually fixed according to the customary rates for unskilled labour in the locality concerned; work of a more special nature, such as sawing and conversion generally, is usually paid for at higher rates. Work is generally carried out either (1) under the direct supervision of an employé of Government or of the owner of the forest, or (2) by contract. In the former case the workmen may be paid either (*a*) by daily labour, or (*b*) by piece-work.

Payment by daily labour is specially necessary where the work has to be carried out carefully and not hurried over, for example, work such as the weeding and cleaning of plantations, in which much care is necessary. Where daily labour payment is made the workmen require to be kept under supervision and made to work for a certain number of hours daily, there being no special inducement towards hard work such as is the case where payment is made by piece-work.

Payment by piece-work means payment by the quantity of work done irrespective of the time taken to perform it, for example, payment for earthwork by volume in cubic feet, or payment for converting into sleepers of a given size at a fixed rate per sleeper. This system has the advantage that there is every inducement towards hard work; on the other hand, it is not suitable for work which if hurried over would be badly carried out, particularly where the results are not readily detected. In the case of tree-felling, payment is sometimes made at certain rates per tree, the rates varying according to the girth of the tree to be felled.

Payment under contract.—In this case a contractor agrees, under certain working conditions, to complete a piece of work in a given time, the work being paid for at a stipulated rate on completion. In this case, although the supervision required is not so constant as where no responsible contractor is in charge, supervision is nevertheless necessary to ensure the terms of the contract being adhered to.

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CHAPTER II.

Methods of Sale.

In this chapter we shall deal with the chief methods under which sales are conducted: these are (1) sale by private bargain, (2) sale by public auction, (3) sale by tender, (4) sale by royalty or fixed tariff.

SECTION I.—SALE BY PRIVATE BARGAIN.

Although this is the method under which much of the petty general business of India is transacted, it is only in exceptional cases applicable to sales of timber and other forest produce by the Forest Department, as it involves much time in bargaining, and is in other ways unsuitable. In special cases sale by private bargain is advisable, particularly where one person desires to purchase but where there is no general competition for the produce to be sold, for example, where a few selected trees of special kinds are required for some particular industry. In such cases the price is fixed according to the current market rates, or, if these are not ascertained, on the averages of past sales, due regard being paid to any changes in the market. This system may also be employed to break up combinations in public auctions.

SECTION II.—SALE BY PUBLIC AUCTION.

Sale by auction literally means sale by increasing (the price), the sale being carried out by two or more persons bidding higher and higher against each other, the bidder of the highest price becoming the purchaser. On the Continent of Europe a commencement is sometimes made with a high price, the salesman calling out a lower and lower price at intervals until some one accepts the price offered. This, though not strictly an auction, is popularly termed a Dutch auction; it occupies more time than the usual form of auction.

In some cases a candle, timed to burn about 5 minutes, is lighted at the beginning of a Dutch auction, and no bids are allowed after the candle goes out; thus in the uncertainty as to when the candle will burn itself out intending purchasers will avoid delaying too long in calling out their bids.

One of the chief disadvantages of auction-sales is the danger of a combination among would-be purchasers, who agree previously not to outbid each other. This can to some extent be prevented by advertising the sale as widely as possible, so that persons from a distance, who have no connection with local purchasers, may attend the sale. To prevent unreasonably low prices being obtained, a minimum price is fixed, known as the upset price or reserve price, below which no bids are accepted. Prior to an auction of timber or other forest produce being held, the produce should be conveniently exposed for inspection some days beforehand in suitable sale lots, lists of the lots with particulars as to dimensions, quality, etc., being prepared for the convenience of intending purchasers: at the same time the auction should be publicly advertised as widely as possible. Before the commencement of the auction it is always necessary to read out the conditions of sale; such conditions fix the period within which payment is to be made, failure to pay within the prescribed period leading to forfeiture of all claim to the produce purchased; they also fix the latest date on which all produce purchased has to be removed from the sale depôt, demurrage being charged after the prescribed date. The conditions of sale also deal with matters affecting the actual conduct of the auction, providing for its closure at any period of the sale if necessary, so that any combination among bidders may be thwarted. It may be advisable to require intending purchasers to sign the conditions of sale before the auction commences, to obviate subsequent objections to any of the clauses.

In the case of large timber sales it is customary to hold the auctions, not in the actual depôt where the timber is lying, but in some room or other place, opportunity having been previously given to intending purchasers fully to inspect and value the several lots exposed for sale; this is necessary owing to the fact that timber is bulky and occupies much space, so that a great deal of time would be wasted if each lot were visited and auctioned *in situ*. In the case of important sales it is often profitable to employ a professional auctioneer and to pay his commission, particularly if the auctioneer is in the habit of selling timber regularly, as he is in touch

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with the market and can usually be depended on to obtain a good attendance at the auction, while he is at the same time responsible for the collection of the amounts bid, thus saving much extra work in the Forest Office. For small local sales the employment of a special auctioneer is hardly necessary.

SECTION III.—SALE BY TENDER.

Under the system of sale by tender, would-be purchasers make offers on or before a fixed date, stating the price they are willing to pay; such tenders are of two kinds, sealed tenders and open tenders.

In the case of *sealed tenders* the intending purchasers submit their tenders in sealed covers before a certain hour on a fixed date: all tenders are then opened, in the presence of the tenderers if they wish to be present, and the terms of each tender are read out. The officer whose duty it is to accept tender need not accept the highest tender, a proviso which should be previously notified in the advertisement calling for tenders: in this way the tenders of persons who are known to be insolvent or to be otherwise undesirable can be disregarded. Tenders usually require to be accompanied by deposits of money known as earnest-money, which are returned to unsuccessful tenderers; this earnest-money is forfeited by the successful tenderer in case of non-fulfilment of his tender. Sale by sealed tender is not always the most profitable form of sale in India, but where it can be introduced successfully it is a good system, as it gives little trouble and is usually effective in preventing combinations.

In sales by *open tender* the tenders may be made at any time, either personally or in writing, by a certain date, and a tender may be accepted at any time before the date notified. In this case bargaining is possible. The system is not altogether a good one, as tenderers quickly realize the price likely to be accepted and may combine accordingly; it is usually suitable only for produce whose value remains fairly constant. It is, however, a useful method of breaking up combinations at auctions.

SECTION IV.—SALE BY ROYALTY OR FIXED TARIFF.

Under this method of sale the disposal of forest produce is governed by fixed prices, being revised from time to time

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as conditions change. The tariff prices are fixed as nearly as possible with due regard to current market rates. This method of sale is largely employed in India, particularly for inferior timber, bamboos, fuel and many forms of minor produce, the royalty, that is, the fixed price, being charged by quantity, weight, volume, or percentage on the market value, the last-named being known as *ad valorem* royalty. In depôts petty produce, such as small quantities of fuel or charcoal, is conveniently sold at fixed rates, while the levy of royalty on forest produce extracted from the forest by purchasers is universal throughout India, the simplicity of the system rendering it particularly applicable in a country where forest produce of all kinds is much in demand for the daily requirements of the people.

CHAPTER III.

Systems of Extraction and Disposal of Forest Produce.

SECTION I.—GENERAL.

In this chapter the more important systems, as employed in India, of extracting and disposing of forest produce, will be described in outline. The number of variations in detail, as applied in different parts of the country, are so numerous, that a consideration of them all would fill a large volume in itself, and cannot be attempted here. It is also quite impossible to state definitely what special system is most suitable or most remunerative in the case of any particular class of timber or other produce, as local conditions vary so much that where a certain system may be found most suitable in one locality it may be quite out of place or unworkable in another.

In deciding on the introduction of any system there are many general questions to be taken into consideration, the chief of which are (1) the maintenance and improvement of the forest, (2) a fair remuneration to the State or forest owner, (3) the prevention of theft or fraud on the part of purchasers or forest employés, (4) the safeguarding of the interests of the local population, (5) the avoidance of unnecessary complication in the system, rendering it unworkable, or unintelligible to those who have to carry out the details, (6) the physical conditions of the locality, (7) the number and qualifications of the staff responsible for carrying out the work, (8) the capability or financial standing of the contractors or purchasers whose duty it is to extract the produce, (9) the quality and quantity of labour available, and (10) the general policy of Government, particularly as regards the encouragement of private enterprise.

The extent to which one or more of these factors can be taken into consideration in the adoption of any system of exploitation will be indicated in the next three sections, which deal with the systems themselves. These systems naturally fall into three main groups, (1) felling and extraction, or

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collection, by Government agency, (2) felling by Government agency and extraction by purchasers, and (3) felling and extraction, or collection, by purchasers. In the case of private forests this classification will also hold good, except that the owner's agency takes the place of Government agency. In Indian official reports only the first and third of the above groups are recognized, and where the working of forests is carried out under the second method it is classed under the first or third, whichever it approximates most nearly. In classification for the purpose of reports this is quite sufficient, but for our purpose the second method should be considered separately because it has to be employed, as will be seen later, in certain special cases.

SECTION II.—FELLING AND EXTRACTION, OR COLLECTION, BY GOVERNMENT AGENCY.

Under this system the felling, extraction, and disposal of timber, or the collection and disposal of minor produce, as the case may be, is carried out entirely by Government, the net profit being obtained by deducting the working expenses from the sale value received. The details of working vary, but in general outline the system consists of extraction of the produce to a sale depôt by persons working on behalf of Government, and the subsequent sale of the produce at the depôt, the sale price being credited to Government as gross earnings.

In the case of departmental extraction of timber on a large scale, a common method is to issue contracts to reliable persons to fell and extract to a Government depôt the trees marked for felling in a certain coupe. The contractor duly delivers the timber at the depôt, being paid at stipulated rates for his work. The timber is then taken over by the depôt staff, who are thenceforth held responsible for its safety. The disposal of the timber from the depôt is then effected by sales, whether by auction, tender, fixed tariff, or otherwise. The contractor's work has to be supervised carefully while in progress, as dishonest contractors are liable to fell more than they have a right to fell, in order to receive more payment, or to sell on their own behalf timber which they are extracting on behalf of Government; contractors are also liable to fell and extract only those trees which are easy of access, leaving trees more difficult to work out. It is often advisable to give

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advances to the contractors, on good security, in order to keep them out of the hands of money-lenders ; such advances may be given as part payment for work done, for example, when a tree has been felled and logged the work done so far may be paid for at its estimated value.

In the case of fuel, departmental extraction has to be carried out in some cases to afford regular supplies, in others to keep down the local prices for fuel where fuel is scarce and prices would tend to rise abnormally if the extraction was entirely in the hands of one or two traders.

Government extraction may also be necessary where a new industry has to be started, or where a new product has to be placed on the market.

In India the extraction of minor produce is carried out by Government only to a comparatively small extent. As a general rule the extraction of minor produce can better be left to private persons, but in special cases Government may have reason for undertaking the extraction itself, for example, in the Central Provinces *sál* resin is collected in small quantities by Government agency, the right of collection not being leased to private persons in case these should wound the trees to obtain more resin. Extraction of minor produce by Government agency may have to be undertaken in the interests of the local jungle tribes. Thus the collection of myrabolans by Government agency was introduced into certain of the Bombay forests in 1880, and proved not only more remunerative than the previously-existing system of farming out the collection, but was much appreciated by the jungle people, who were thereby made less subject to oppression and were brought into more intimate relations with the Forest Department. The actual method employed was to establish depôt stations to which the jungle tribes could bring in myrabolans and receive fixed rates of payment for them ; this gave them an inducement, from personal motives, for assisting in the protection of the trees. Among other examples of departmental extraction of minor produce may be mentioned the tapping of pine resin in the Himalayas and the collection of all minor produce in the Nallamalais, Madras Presidency.

The general policy of Government is to limit departmental extraction and to encourage extraction by purchasers. This is on general principles a good policy, as the system of departmental extraction has its drawbacks, the chief of which are (i) a large amount of work, both executive and clerical, is thrown upon the staff, who might be more profitably employed in works of maintenance and improvement of the forest, (ii) the details of extraction and disposal of the produce are often of a purely commercial nature, better suited to private enterprise than to the operations of a Government department, (iii) Government extraction must bring the Forest Department in many cases into direct competition with private firms, a state of affairs which as a general rule cannot be regarded as sound. It is, therefore, only in cases where local conditions actually make it advisable, that the system of departmental extraction in India can be considered to be advisable.

That the system of departmental extraction is not nearly so extensive in India at the present day as that of extraction by purchasers may be seen from the fact that during the five years 1904-05 to 1908-09 five times the quantity of timber and fuel, and nearly 30 times the quantity of bamboos, were extracted by purchasers as compared with the quantity extracted by Government agency, while the value of minor produce extracted by purchasers was more than 13 times the value of that extracted by Government agency.

SECTION III.—FELLING BY GOVERNMENT AGENCY AND EXTRACTION BY PURCHASERS.

This system is followed in cases where great care is necessary to avoid damage to the forest during felling. It is often employed on the Continent of Europe, where trained gangs of woodcutters, working directly under Government, are continuously employed in the forest. The system is to some extent followed in India, and may be usefully employed in the case of thinnings, the stems being felled by skilful woodcutters, and removed, after felling, by purchasers. This system may also be adopted in the case of improvement fellings, where inferior trees are felled for the benefit of the stock as a whole; felling by departmental agency ensures that none of the trees will be left standing.

SECTION IV.—FELLING AND EXTRACTION, OR COLLECTION, BY PURCHASERS.

There are many different methods under which timber and other forest produce may be disposed of to purchasers, but

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for the sake of convenience they may be grouped into four main heads, (1) sale of a whole coupe or area, (2) sale of a few selected trees, (3) sale by means of licenses or permits, (4) sale by the commutation system, and (5) extraction without any previous permit or agreement.

1. *Sale of a Whole Coupe or Area.*

Under this head may be included a variety of systems of great importance, the chief of which are as follows :—

(1) SALE BY LEASE.

This consists in selling the right over a given area to one person or firm, known as the lessee, to extract timber or other produce for a fixed period, which may extend to one or more years. The sale value is realized either in a fixed lump sum payable in one amount or by instalments, or by payment of royalty on the produce extracted, whether by volume, weight, quantity, or *ad valorem*.

The simplest form of lease is that in which a lump sum is paid for the privilege of extracting as much produce of a certain kind as the lessee can obtain in a given time. It is obvious that if this system were to be applied to produce such as timber or fuel the forest would soon be ruined ; the system however, can be suitably applied to crops such as grass, fruits, flowers, etc., which are produced annually, and the whole of which can be removed without detriment. This simple form of lease by lump sum is known as "farming" the crop. Lac can be conveniently farmed in this way, provided suitable conditions are made to ensure the propagation of lac for future use ; for this purpose leases extending over several years are necessary.

There is nothing so dangerous as the habitual lease of a forest for the extraction of dead timber. It may be permissible if certain classes of dead trees or timber are known to exist and have been duly marked, the area being opened to extraction for a definite period ; but if the same area be leased year after year to the indiscriminate extraction of dead timber the chances are that the lessee will make certain, by killing trees artificially, that the annual supply of dead trees is maintained.

The same applies to the extraction of dead wood under any system. Similarly dead wood rights and privileges should not be allowed indiscriminately, but should be confined to certain coupes and fixed seasons.

When a lease is issued a carefully worded agreement should be drawn up, the conditions of which should be a safeguard against damage to the forest by the lessee or his employés.

A system largely followed in Burma, whereby teak timber is felled and extracted by timber firms, is commonly termed a timber lease, though the term purchase-contract would be less confusing, as the system is not a lump sum lease such as that already described. The teak trees are selected over definite areas by trained officers, under sylvicultural rules, and are killed by girdling in order to allow the timber to season and become light enough to float out. The area is then "leased," commencing the third year after girdling, to a timber firm, which is allowed a certain number of years to fell and extract the girdled timber, royalty being paid at stipulated sums per cubic foot after the timber has reached a measuring station and has been measured. After payment of the royalty due the timber becomes the sole property of the firm.

(2) SALE OF STANDING TREES BY COUPES.

(*a*) *Wholesale system.*—This is one of the most suitable and profitable of systems where it can be successfully introduced. The trees are selected and marked, the whole coupe being then sold standing, either by auction or by sealed tender. The sale price can be recovered either in a sum representing the sale value of the coupe as a whole, or at so much per tree of different size classes and species, or on the volume of timber extracted, whether in the round or after conversion. In the absence of a good class of timber traders the system may at first be difficult to introduce, in which case the coupe may be sold by private bargain to one trader on easy terms: once the profitable nature of the business becomes known there is usually no difficulty in obtaining numbers of applicants. The annual coupes are usually sold during the rains, the successful purchasers commencing work as soon after the rains as possible and extracting the material during the following dry season. In many cases it is preferable to extend the lease over two or more years, particularly where the area to be worked is extensive or remote, rendering it necessary for the purchaser to spend time and

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money in collecting labour, animals and materials on the spot.

(*b*) *Monopoly system.*—Under this system trees for felling are marked over a coupe or convenient subdivision of a coupe, and are sold by auction. The price paid for the coupe is known as the monopoly price, as it gives the purchaser the sole right to fell and extract timber from the coupe. In addition to this monopoly price the purchaser pays royalty on all timber brought out of the forest, whether in the round or after conversion: for this purpose a regular scale of export rates is made out for every variety and class of timber, these rates being calculated at about half the value of the timber. When the coupe is marked for felling an estimate of its probable yield is made out; from this, as well as from the scale of export royalty rates, the purchaser is able, after inspecting the coupe, to calculate what monopoly price he can safely give.

The great advantage of this system is that purchasers are induced to remove inferior timber, as they have already paid as the monopoly price about half the value of the timber of the coupe, and it is in their interest to extract everything they possibly can, the royalty rate being so low as to make it worth their while to extract inferior timber as well as the better classes of timber. The monopoly system further allows of variations in the sale price according to the distance of the coupe from lines of export, without the inconvenience of having to fix a separate scale of royalty prices, because the monopoly price paid would naturally be less for difficult localities than for those from which extraction is easy.

The monopoly system has received a fair trial in parts of the United Provinces, and has under certain conditions proved a satisfactory system. It would not, however, be applicable in large unwieldy charges where supervision is difficult, as the estimate of the value of the coupe has to be made personally by a responsible officer.

2. *Sale of a few selected Trees.*

This consists in selling, usually by private bargain or by fixed tariff, a few selected trees. It is not a system to be adopted generally where regular working is in progress, but it is often necessary in special cases, as in sales to public departments, or the sale of certain species of trees for which there is no general demand, but which are in demand for one particular purpose or industry.

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3. *Sale by Means of Licenses or Permits.*

The method of sale by licenses is of very extensive application in India, and has more variations in detail than in the case of any other form of sale. The most typical method is for an intending purchaser to apply, to a person empowered to issue it, for a license to extract timber or other forest produce of certain descriptions in a specified area and within a fixed limit of time, a fee being paid for the license : all particulars are clearly entered on the license, the amount paid for it being written in words and in figures. The licensee then proceeds to collect and extract his produce, which is checked at a specified place within or reasonably near the forest ; if the produce extracted is in accordance with the particulars entered on the license it may then be removed, the license being delivered up and a removal pass being issued in its place, authorizing the licensee to remove his produce to its destination, where it may again have to be checked with the removal pass. Licenses may be in duplicate or in triplicate ; in the former case the original is given to the licensee and the counterfoil is sent up with the accounts of the vendor, while in the latter case the extra foil is issued to the person whose duty it is to check the produce extracted, this foil being sent to the audit office independently of the counterfoil sent by the vendor.

In actual practice there are a large number of modifications of this type, due to local conditions. As regards the person empowered to issue licenses for valuable material, such as timber of the better kinds, none but a responsible officer of fairly high grade should be allowed to issue them. For petty minor produce, head-loads or cart-loads of dry fuel, bamboos, etc., this would be impracticable, and hence licenses for such have to be issued either by low-paid officials or by persons temporarily appointed for the purpose, the latter being paid either by a fixed salary or by commission on the revenue collected by him. To guard against fraud security usually has to be furnished, while in some places the license-vendors are frequently transferred from one post to another ; in any case frequent inspection of their books is necessary, while as many of the orginal licenses as possible should be recovered and compared with the counterfoils and cash accounts, a frequent form of fraud being to enter a smaller amount in the counterfoil and in the accounts than is actually collected and entered on the original license. The purchase of licenses for petty forest produce should be made as convenient as possible for the persons who desire to obtain produce, otherwise the temptation to steal it is increased: for this reason the license-vendors should be posted at convenient places near the forest. The work of issuing such licenses is sometimes entrusted to village headmen, with good results, as these men hold more or less responsible positions, while they are brought more into touch with the Forest Department, receiving as they do emoluments in the shape of commission on revenue received for the sale of licenses. Under any circumstances it is not advisable to allow the Forest protective establishment to issue licenses, as it is their duty to check them while in operation.

Among special forms of license systems may be mentioned the face-value system, including the use of tickets, and the employment of adhesive stamps. By the face-value system is meant the sale of licenses, usually of different colours, each representing a definite value, so that illiterate persons soon get to know the value of the different coloured licenses. Such licenses are sometimes in the form of cardboard tickets resembling railway tickets. In some cases adhesive stamps, resembling postage stamps, are affixed to the back of the license when the latter is issued, the value of the stamps corresponding to the amount paid for the license. The stamps are punched and dated when the license is issued, so that they may not be used after the expiry of the license.

4. *Sale by the Commutation System.*

By commutation is understood the payment of a fixed sum once in a fixed period, usually a year, in return for the privilege of being allowed to remove certain classes of forest produce at any time and as often as is necessary. The system should never be employed except in the case of petty produce required for *bonâ fide* domestic use, and not for sale or barter. Such produce as thorns for village hedges, litter, grass, and other small classes of minor produce, may be removed under this system, while exceptionally the extraction of small timber for agricultural or domestic use, and fuel, may be allowed on payment of commutation fees. The system is, however, most applicable to forest grazing. The chief difficulty is to obtain a correct estimate of the number of cattle to be grazed or the quantity of each class of produce to be removed, in order to fix a fair commutation fee: this is done

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by making an annual census of cattle or an annual estimate of the quantity of forest produce required, based on the number of persons in each village. Commutation fees are usually levied from a whole village, in which case no commutation should be allowed in any village unless the whole village agrees to commute.

5. *Extraction without previous Permit or Agreement.*

Under this head may be included two different forms of realizing revenue on forest produce extracted without license; these are (1) the system known in India as the *kham tahsil* system, and (2) the levy of export duty.

(1) THE KHAM-TAHSIL SYSTEM.

Under this system a person may enter a forest without previous permission and collect forest produce of certain specified classes, which he brings out, and on which he pays duty at a revenue-station on the line of export, receiving a receipt for the amount paid in the shape of a removal pass. This system is obviously applicable only to tracts which have not yet been brought under an efficient state of forest management, and is suitable only for remote tracts from which it is possible to remove the produce only by one or two well-defined lines of export, otherwise the risk of escaping the payment of duty would be too great. Under any conditions it is very difficult to exercise an adequate check on produce brought out, while the detection of fraud on the part of the revenue-collector is equally difficult. The difficulty can to some extent be avoided by establishing a second check station further down the line of export and at a considerable distance from the first station, so that the produce may be independently checked and compared; independent inspecting officers should also frequently patrol the line of export.

As far as the forest itself is concerned this system is open to the gravest objection, particularly where timber or fuel is the produce extracted, because there is little or no safeguard against excessive and wasteful felling.

A rough form of the *kham tahsil* system is employed in some places in the interests of jungle tribes, who, however, are in this case not purchasers. The jungle people bring produce down to Government sale depôts situated conveniently near the forest; they are paid for the work of collection and extraction either at fixed rates or by percentage on the sale

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price of the produce. The purchaser of the produce at the depôt obtains a removal pass which enables him to export it to its destination.

(2) EXPORT DUTY.

A system has recently been brought into operation in Burma whereby an export duty is collected at seaport towns on all cutch, lac, and caoutchouc exported from the country. The system was first adopted in the case of cutch owing to the difficulty formerly experienced in collecting within the country the legitimate revenue due to Government on that product; as the great bulk of the cutch manufactured in Burma is exported by sea, the realization of duty at seaport towns covers nearly all the cutch manufactured. The cutch trees (*Acacia Catechu*) within Government reserved forests are strictly protected and may not be felled unless sold under some well-regulated system, but all cutch trees growing on any other class of land may be felled and converted into cutch without payment, a free license only being necessary. Formerly the revenue on cutch was collected by the issue of licenses fixing the number of cutch-boiling cauldrons of given capacity which might be employed within a given period: as such licenses applied only to Government waste land, and as cutch on private land could be boiled to any extent without license or payment of duty, it is not to be wondered at that cutch-boilers on private land extensively stole cutch trees from Government land to convert free of duty. On this account the system of export duty was introduced; it covers cutch obtained from private as well as from Government land.

A great advantage of this system is that the inhabitants of the country obtain what they require duty free and thus more cheaply.

PART IV.

FOREST INDUSTRIES.

Among the large number of industries connected with Forestry we can here deal with only a few of the local industries which more directly concern the subject of Forest Utilization, and are in some cases carried out in or near the forest itself: the industries in question are the following:—

I.—The manufacture of charcoal.
II.—The manufacture of turpentine and colophony.
III.—The extraction of various oils and tars.
IV.—The distillation of camphor.
V.—The manufacture of cutch and kath.
VI.—The preparation of tannin extracts.
VII.—The manufucture of paper-pulp.
VIII.—The antiseptic treatment of wood.
IX.—The pressing and baling of hay.

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CHAPTER I.

The Manufacture of Charcoal.

Section I.—General.

When wood is burnt in the presence of air it is converted into gases with a small quantity of ash left as residuum. If air be entirely excluded during burning, however, the wood will be converted into a number of gaseous and liquid products, such as carbon dioxide and monoxide, hydro-carbons, acetic acid, wood-alcohol, tar, etc., the residuum left behind being charcoal. Thus the manufacture of charcoal, or the carbonisation of wood as it is called, is carried out by burning wood out of contact with the air, and is a form of destructive distillation. During the burning about half the carbon is expelled, and the charcoal consists of what remains of the carbon, oxygen, and hydrogen, as well as all the ash constituents, the carbon constituting about 90 per cent. of the whole.

From the foregoing remarks it will be seen that in converting wood into charcoal a considerable amount of waste takes place : this, however, is more than compensated for by the advantages of charcoal over firewood. The chief of these advantages are (1) charcoal is easier to light, and gives out a steadier and more intense heat, than firewood, burning with a smokeless flame ; the heating power of charcoal is nearly twice that of the same weight of wood : (2) it is always ready for use, and does not require to be split or cut up like wood : (3) it is more portable than wood, and can be transported to greater distances ; the weight of charcoal is less than a quarter of the weight and less than half the bulk of the wood from which it is made.

There are three methods of charcoal-making, in *retorts*, *pits*, and *kilns*.

Charcoal-making in retorts is as yet of little practical interest in India and is carried out more for the sake of obtaining secondary products such as acetic acid, tar, alcohol, etc., than for the sake of the residuum of charcoal. In this method of manufacture wood is closely stacked in permanent air-tight retorts or ovens made of masonry or iron, which are heated, the various products of destructive distillation being collected, and the charcoal remaining behind after combustion is completed.

Charcoal-making in open pits is a most wasteful method, and should be employed only where wood is very abundant and has very little value. It is a useful method on road-making where a small quantity of charcoal is required daily for repairs to tools. A hole with sloping sides is dug in fairly stiff soil to a depth of about 3 to 5 feet and a diameter of about 5 feet. This is filled with dry twigs and small branches, which are fired and allowed to burn until all smoke has ceased. More twigs and branches are then thrown in, and the operation is continued until the pit is full of glowing charcoal, when it is covered over with turf or moist earth, so that all air is excluded. In a day or two the pit becomes sufficiently cool to be opened, and the charcoal is taken out. The wastefulness of this method is due to the fact that the burning is carried out with almost free access to the air, so that much of the wood is consumed instead of being converted into charcoal. It requires little skill, however, to manufacture charcoal in this way.

Charcoal-making in kilns is the most important method for forest purposes, so that a detailed description of the processes of manufacture will be necessary.

SECTION II—CHARCOAL-KILNS.

There are many different ways of constructing charcoal-kilns, but they approximate more or less to a few types which will be described below. Whichever method is employed there are a few general rules which should be carefully observed. It is advisable that all the wood should become carbonised as far as possible simultaneously, because if some pieces become carbonised long before the remainder they are liable to become partially or wholly consumed. For this reason different woods varying much in density should not be burned in the same kiln. Another objection to burning woods of different densities in the same kiln is that the charcoal produced by different woods is sometimes used for different purposes; hence the woods should be kept separate from the beginning, as the charcoal cannot be conveniently separated afterwards. To ensure even carbonisation very thick pieces of wood should be split to convenient size, and not stacked whole along with smaller sized billets, as the thick billets take much longer to burn than the smaller ones. In order to ensure the admission of as little air as possible the wood to be carbonised should be stacked as closely as possible, the pieces being dressed straight for this purpose, and the interstices being filled up with smaller billets and chips of wood. Unsound wood should on no account be used, as it will produce no charcoal. Charcoal-kilns vary considerably in the method of stacking, which may be horizontal or vertical, the manner in which the kiln is fired, the shape of the kiln, and other details; it will be sufficient for our purpose to describe a few of the chief types; these are (1) the paraboloidal over-ground kiln, (2) the oven kiln, (3) pit kilns, (4) the prismatic kiln, and (5) the hill kiln.

1. The Paraboloidal Over-Ground Kiln.

(1) Shape and Size of the Kiln.

The usual shape of the kiln is that of a paraboloid (*vide* Plate XXI fig. 1), the volume of which is $\pi r^2 \times \frac{h}{2}$, where r is the radius and h the height, or, in terms of the circumference c, the volume is $\frac{c^2h}{8\pi}$. Usually 4 to 6 per cent. of the volume should be deducted, as the kiln has as a rule steeper sides than a paraboloid.

Kilns vary greatly in size. A convenient size of kiln is obtained by making the height 8 feet and the radius 8 to 10 feet: this gives a capacity of about 800 to 1,200 stacked cubic feet. The larger the kiln the less space it occupies and the less covering material is required in proportion to the amount of wood used, while fewer men are required for looking after one large kiln than for supervising several small ones; on the other hand a large kiln requires more skill in handling than a small one. In Europe small kilns have a capacity of 400 to 1,000 cubic feet stacked, and large ones a capacity of 2,000 to 3,500 cubic feet. In India the capacity is seldom more than 1,500 cubic feet.

(2) Site of the Kiln.

The site for a kiln should be level and even, and situated in a sheltered place and in close proximity to water. The

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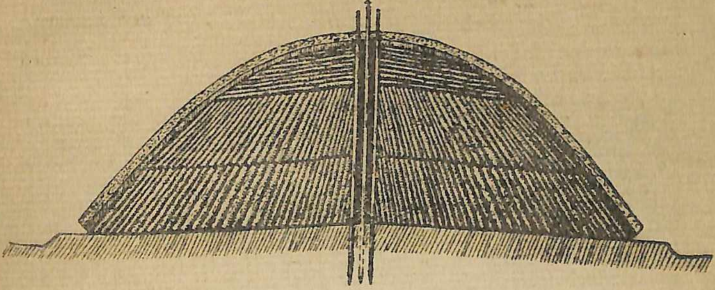
PLATE XXI.

CHARCOAL-BURNING

1



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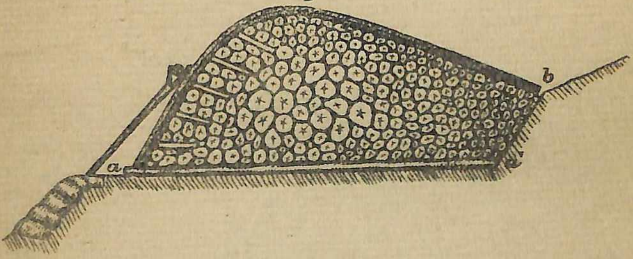

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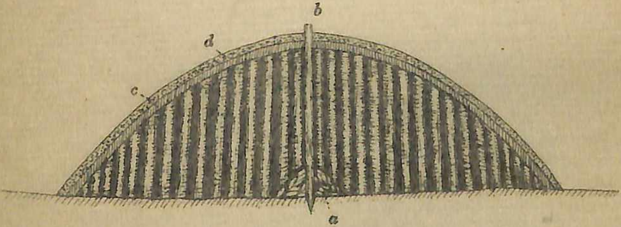

1. Charcoal-burning—paraboloidal over-ground kiln.
2. „ „ —hill-kiln. *a. a'.* Firing passage. *b.* Vent-hole.
3. Aravalli paraboloidal kiln. (*a*). Inflammable material. (*b*). Central stake, removed before firing. (*c*). 3″ layer of grass. (*d*). 3″ layer of earth.

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nature of the soil is important: if it be too porous too much air will be admitted into the kiln from below, while if it be too stiff it does not sufficiently absorb the liquid products of carbonisation, and will unnecessarily retard burning. A sandy loam is the most suitable, but it is above all necessary that the ground should be uniform, otherwise the kiln will burn unevenly: for this reason all vegetation should be removed by the roots, all stones should be taken out, and the site should be raised about 8 to 12 inches in the centre, sloping outwards evenly to the circumference, to allow such liquid products as are not absorbed by the soil to run out.

After the site has been thus carefully prepared it should be allowed to settle for two or three months until it becomes firm. Before the kiln is built the site, if at all damp, should have a layer of dry brushwood and leaves burned on it.

The best form of site is an old site which has been used previously, but even then the surface should be prepared again if at all uneven, the small pieces of charcoal lying on the site being broken up and mixed with the soil.

The site should be traced out in the form of a circle of the required radius. It is advisable, when there is much wood to be carbonised, to have several kilns close together.

(3) BUILDING THE KILN.

The kiln is built up by two tiers of billets stacked vertically, and a third, the topmost, stacked horizontally (*vide* Plate XXI, fig. 1). If the vertical billets are cut 3 feet in length, and the topmost tier is stacked 2 feet thick in the centre, the height of the kiln will be 8 feet, which, as stated above, is a convenient average height. Large kilns may be composed of more than two tiers of vertical stacking.

Before stacking is commenced it is necessary to construct a flue or chimney up the centre. This is done by driving three upright stakes into the ground in the centre of the site, the stakes being a foot apart and forming an equilateral triangle; their height above ground should be at least equal to the total height of the kiln. These stakes are bound round with withes or twisted grass so as to form a hollow chimney, which is filled with dry combustible material, such as straw, shavings, chips of wood, or branches. The kiln may be fired either from above or from below: in the former case the smallest pieces are placed on the top, and in the latter case they are placed below. A small board is usually placed on the ground at the bottom of the flue to keep off the damp of the soil.

To ensure a correct shape for the kiln, the circumference should be carefully pegged out in the form of a circle. The stacking then commences from the centre. The billets are all cut to the same length, trimmed straight, and stacked as closely as possible; they should rest on their thick ends so that the necessary slope of 60° to 70° may be given to the outside of the kiln. A few thin split billets should be placed next the chimney to ensure the wood catching fire readily. The thickest billets should be placed where there will be most heat, that is, about half-way along the radius. Great care should be taken to see that the regular paraboloidal shape of the kiln is maintained during stacking, while all interspaces should be filled up with smaller pieces of wood.

If the kiln is to be fired from below, a narrow passage, extending along one radius from the centre to the circumference, should be constructed along the ground; this is necessary for lighting purposes. This passage is made by laying a straight pole along the ground, carefully stacking the billets over it in the form of an X, and withdrawing the pole after the stacking of the kiln is completed.

The stacking of the two lower tiers, and even of all three tiers, can proceed simultaneously. The second tier is stacked in the same way as the lowest tier, but the top tier is stacked horizontally, various sized billets being used, so that the rounded shape of the top of the kiln may be obtained.

(4) COVERING THE KILN.

In order to exclude all air except what is absolutely necessary to maintain combustion, the kiln has to be covered over with some material pliant enough to yield without breaking as the kiln subsides during carbonisation. It has been found by experience that the best covering consists of two layers, an inner layer composed of turf, soft green grass, leafy twigs, ferns, moss, or green weeds, and an outer layer of wet earth, preferably mixed with charcoal dust, which is plastered over the inner covering: this outer covering should consist of fine earth free from stones and other large fragments. The inner covering is laid on commencing from above, and should be thick enough to prevent the earth of the outer covering from falling through. It should not be made too thick near the ground level until combustion has

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well started, when it can be closed up. The chimney should also be kept uncovered till the kiln is well alight.

The outer covering is usually plastered on commencing from below, and should be thicker on the top than on the lower parts. Round the ground level the kiln is frequently left uncovered at first, the covering being applied as burning proceeds. The covering has to be kept from sliding off the steep sides of the kiln; this is done by supports consisting of upright forked sticks a few feet apart, with horizontal poles resting on the forks. Two or three tiers of such supports may be necessary.

If the kiln is not in a sheltered place a screen of branches or thatch-grass should be erected on the windward side of it.

(5) Firing the Kiln.

If the firing is done from the bottom, a pole with a bundle of burning straw tied to the end of it is pushed along the passage made for the purpose, and the inflammable material in the chimney is set alight ; as the material in the chimney sinks during burning more material is stoked in from the top until the kiln is well alight, after which the chimney is filled tight with short billets of wood to prevent the stacked material from falling in. The lighting passage is then also filled with billets, and its entrance, as well as the top of the chimney, is covered over.

In firing from above, a dish of live charcoal is thrown in from the top ; the burning charcoal is then mixed up with the inflammable material in the chimney by means of a stick. When the kiln is well alight the chimney is filled, as before, with short billets and the top is covered.

Firing from below renders the stacking more difficult than firing from above, but the latter is less certain in its results than the former, as the fire, if applied from above, may fail to reach the bottom of the chimney, causing retardation in the carbonisation of the lowest tier.

(6) Method of Conducting the Burning.

When the kiln is well alight the fire spreads outwards from the centre in the form of an inverted cone with the base gradually widening outwards. The first sign of burning is that bluish-grey vapour issues forth from the surface of the kiln ; this is followed by a thick pungent yellowish brown smoke, which in turn gives place to a clear blue flame when carbonisation is complete. From these characteristic signs the charcoal-burner can trace the progress of the burning.

Theoretically the burning should proceed evenly all round the kiln until it reaches the base, when the whole kiln becomes carbonised. In practice, however, this is never attained, owing to unequal stacking, currents of air, and other circumstances : hence it is necessary to regulate the burning so as to keep it as even as possible. This is done by making small holes through the covering with a stick just in front of the line of burning in places where the combustion is too slow. Where the burning is proceeding too fast the covering should be thickened. In this way the charcoal-burner should endeavour to keep the circle of smoke at the same level all round the kiln. All holes should be closed up as soon as the blue flame appears after the thick smoke, as this is a sign that the charcoal is on fire : fresh holes should then, if necessary, be made lower down.

During burning the contents of the kiln subside through loss of volume : this causes cracks to appear in the covering, while hollows are sometimes formed, the covering sinking and often breaking. All cracks should be mended at once as they cannot usually be closed up by plastering them over, the best way to mend them is quickly to break off all loose edges and replace them with fresh mud. Hollows should be filled up at once ; this is done by removing the covering quickly, pushing in fresh billets, and covering over the gap as rapidly as possible. The charcoal-burner should frequently tap the sides of the kiln with a thick stick to detect the presence of hollows before the covering actually falls in.

The kiln has to be watched carefully by night as well as by day. Before nightfall all cracks and hollows should be filled up, and the cover thickened on the side from which the wind is expected to blow, and especially round the base of the kiln, where draughts are most liable to enter. At intervals during the night the kiln should be examined for cracks and hollows, and a supply of dry straw or grass should be ready for lighting in case light is required in an emergency.

When the smoke has reached the base of the kiln, and has been replaced by blue flame, which in turn disappears, the carbonisation is complete, but as the charcoal smoulders for some time after it should be carefully watched, the covering being thickened where necessary to prevent the outbreak of fire.

(7) OPENING THE KILN.

The great danger in opening a charcoal-kiln is that the charcoal takes some time to cool, and may burst into flame if the kiln is opened too soon. For an average-sized kiln the kiln should, if possible be left for a week or more before opening. If this is impracticable it may be opened sooner if proper precautions are taken: for this purpose the kiln should be opened only at night, when the air is damp and cool, and because smouldering pieces can then be easily detected. A small section of the kiln is broken down on one side, the charcoal is raked out, and the hole is quickly covered up again; all smouldering pieces are separated and covered with earth until the glow is extinguished, or a small quantity of water may be used for this purpose. A new hole is then made in another part of the kiln, and more charcoal is taken out: this operation is repeated at different points in the side of the kiln until all the charcoal has been extracted. Water should never be poured over the charcoal in large quantities, as it spoils the quality of it.

As soon as the charcoal is cool enough it should be sorted and put away under cover, as it absorbs moisture readily. Even if the greatest care is taken in the carbonising operations it will be found that some of the wood is not completely converted into charcoal; such half-carbonised wood should be kept for use in kindling fresh kilns.

(8) MODIFICATIONS OF THE PARABOLOIDAL KILN.

There are many modifications of the paraboloidal kiln, among which may be mentioned the Aravalli kiln, used in Merwara, the chief advantages of which are that it requires no water in its construction, and that it takes only 24 to 36 hours to burn, being small in size. The average capacity is 200 to 300 cubic feet of stacked wood. In this kiln, shown in Plate XXI, fig. 3, the stacking is done vertically with one tier of billets of varying length, usually from 3½ feet downwards, the longest being towards the centre and the shortest towards the circumference. The covering consists of a 3-inch layer of grass, over which is a 3-inch layer of earth rammed tight. The total height of the kiln is thus about 4 feet as a rule. Firing is done from above: an upright stake placed in the centre of the kiln before stacking, having a heap of inflammable material at its base, is withdrawn, and burning charcoal is thrown into the hole formed, the kiln being thus set alight.

2. *The Oven Kiln.*

The distinguishing feature of this form of kiln, which is shown in Plate XXII, is a thick covering of mud which at the first burning of the kiln becomes baked into a hard crust. The charcoal is taken out through a hole made in the side of the hard covering, which can then be re-filled with wood and used again several times. These kilns are commonly seen in Oudh.

The details of manufacture in such kilns vary. In some localities they are built entirely above ground and in others a circular hole 1½ feet deep is dug as a foundation for the kiln. These kilns are paraboloidal in shape, and vary from 9 or 10 feet to about 14 feet in diameter, the height being about 6 or 7 feet. The wood is stacked vertically as in the ordinary paraboloidal kiln, and an outer covering of mud is plastered over an inner layer of leaves to a thickness of some 6 inches. No chimney is used, the kiln being fired through holes in the covering at ground level: a hole, however, is sometimes left in the top until the wood is well alight.

During the burning, which occupies from three to ten days, hollows are not broken in and filled up as in the ordinary paraboloidal kiln, but the covering is allowed to bake into a hard crust. Cracks are plastered over with wet mud wherever they occur. After burning is completed the charcoal is allowed to cool for two days, when the kiln is opened by breaking a hole in the side. After the charcoal is removed the kiln is re-filled with wood and again kindled.

The yield of charcoal is smaller in the first burning than in the subsequent burnings.

3. *Pit Kilns.*

A pit kiln is a kiln the lower part of which is stacked within a pit dug in the ground: the object of this pit is partly to reduce the area over which the covering has to be made and looked after, and partly to facilitate the exclusion of air. The depth of the pit varies, but where it is great vent-holes have to be dug obliquely through the ground leading to the bottom of the pit. A convenient form of pit is a circular pit 1 to 2 feet deep: the shape of the

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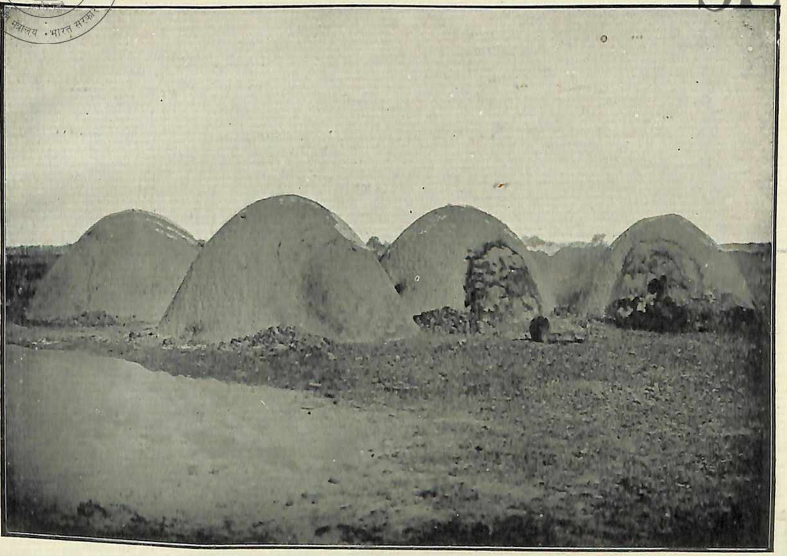
CHARCOAL-BURNING (CONTD)—THE OVEN KILN.

PLATE XXII.



OVEN KILNS IN PROCESS OF BURNING.

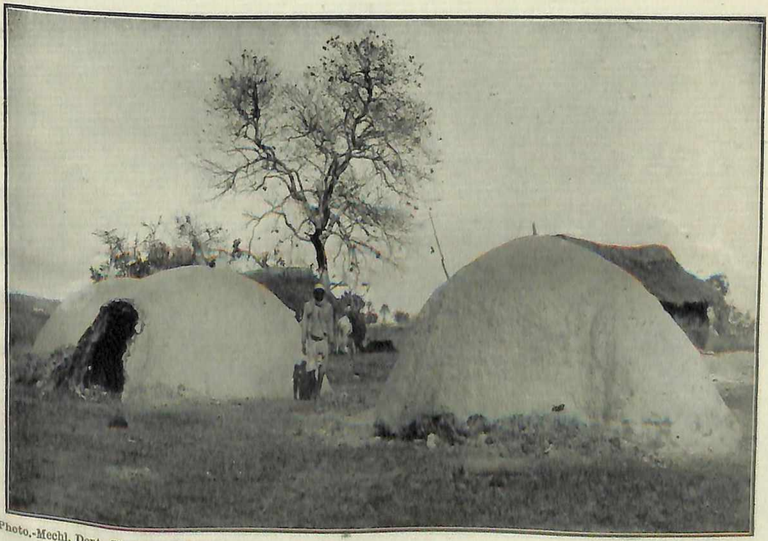


Photo.-Mechl. Dept., Thomason College, Roorkee.

Photos. by Author.

BURNING COMPLETED. KILN ON LEFT EMPTIED; THAT ON RIGHT STILL UNOPENED.

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kiln would then be paraboloidal. At the bottom of the pit a layer of dry leaves and twigs, 4 to 6 inches deep, is first spread, to ensure the firing extending along the bottom of the pit and also to absorb liquid products, which cannot escape from the pit.

The stacking may be either horizontal, or vertical as in the paraboloidal over-ground kiln; the former is usually adopted. When stacking a pit kiln horizontally, pieces of different size are used, some being placed radially and some tangentially; each layer should be packed closely before the next layer is placed on it. The advantage of horizontal stacking is that billets of all sizes may be used.

Up the centre of the kiln a chimney is constructed, and firing takes place from the top. The sides of the kiln at the ground level should be kept open until the fire has spread some distance down into the kiln, while it may be necessary to keep one or two holes open at the ground level until carbonisation is complete.

Horizontal stacking, owing to the fact that billets of all sizes can be used, is less expensive than vertical stacking: it is, however, difficult to do well, but this is not such a serious drawback where the pit kiln system is employed, as where the stacking is done entirely above ground. The outturn of charcoal from horizontally stacked pit kilns is considerably less than that obtained from over-ground paraboloidal kilns. Where skilled charcoal-burners are not available the horizontally-stacked pit kiln is a suitable form to adopt.

4. *The Prismatic Kiln.*

The name given to this form of kiln hardly describes its shape. The base is a rectangle, but the sides are more or less rounded. In this form of kiln the wood is stacked horizontally, and its chief advantage is that the pieces do not require to be cut up so small as in other methods: the most convenient mode of stacking is to place all the longest pieces at the bottom, running, if necessary, throughout the whole length of the kiln. There is no chimney, but a passage is left along the ground, extending from one end of the kiln to the other; this is filled with combustible material and fired from both ends. The prismatic kiln is easy to construct, but is somewhat difficult to cover, and is liable to breakage through unequal settling.

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5. *The Hill Kiln.*

This is a special form of kiln, usually of small size, adapted for hilly country, where level sites are difficult to obtain and strong winds make the conduct of burning operations difficult. The base of the kiln is rectangular, and its general shape is shown in Plate XXI, fig. 2, which gives a longitudinal section through the kiln.

The site of the kiln is prepared by making in the side of a hill a cutting, the base of which should slope slightly outwards ; the side of the cutting should slope at an angle of about 60°. The site should be allowed to settle for some time before use, as the outer part is made of earth.

As the kiln is sheltered on the hill side and exposed to winds on the valley side, the carbonisation will be more rapidly carried out on the latter side ; hence towards the outside the kiln should be highest and should contain the largest billets. The wood is stacked horizontally, and a passage (*a a′*) is made along the ground, extending right through the kiln from front to back ; this is filled with combustible material, and is used for firing the kiln. The usual covering is applied over the kiln, but a vent-hole, *b*, is left at the back ; this is kept open until carbonisation is nearly complete. The outer face of the kiln, being steep, has to be supported by struts, as shown in the diagram. The front of the firing-passage is left open until the kiln is well alight, when it is closed and holes are made in the sides of the kiln and at either side of the vent-hole *b*, as required.

SECTION III.—YIELD OF CHARCOAL.

The amount of charcoal yielded by a given volume of wood varies according to the circumstances under which the burning is done : in unfavourable weather, or where the stacking and burning is carried out carelessly or unskilfully, the yield will be comparatively small. Assuming, however, that the burning has been properly done in favourable weather, the yield will still depend on the nature of the wood used and the system of carbonisation employed. As regards the wood, dry wood will naturally yield a greater proportion of charcoal for its volume and weight than green wood, as the former has already shrunk and lost weight to a certain extent. Resinous or oily woods usually produce more charcoal than other kinds, owing to their greater inflammability, which ensures proper burning throughout the kiln.

The method of burning employed affects the yield of charcoal considerably. It has already been said that the most wasteful method is the open pit method.

In specially built retorts the yield is largest. As far as kilns are concerned, an accurate comparison of the yield from the various kinds of kiln is not possible without reliable figures, which are not available. A fair yield of charcoal from any kiln is usually put down at 20 to 30 per cent. by weight. Figures from Kheri, Oudh, give the yield by weight of charcoal made in oven kilns at 36 per cent. Figures regarding charcoal have, however, to be accepted with caution, because charcoal absorbs moisture rapidly and increases considerably in weight during damp weather; hence comparative figures can be accurate only if the charcoal is weighed immediately it is taken out of the kiln, and even then there may be local climatic conditions which affect the yield differently in different places. For these reasons a comparison of the various kinds of kiln as regards quantity of charcoal produced would be misleading. It has been proved, however, that where firing is done from below, the yield is usually greater than where the firing is done from above, because in the former case the fire spreads more readily through the entire kiln, carbonising a larger proportion of wood than if the firing is done from above. Vertical stacking is also said to produce a higher yield than horizontal stacking, though much will naturally depend on the care and skill of the charcoal-burners.

SECTION IV.—PROPERTIES OF GOOD CHARCOAL.

Charcoal is a dry, black, porous, but fairly hard substance, with a lustrous appearance, of low specific gravity, and without taste or odour. Its weight is more or less proportional to the weight of the wood from which it is made. Charcoal absorbs moisture readily, and in damp weather weighs considerably more than it does in dry weather; hence it is preferable to sell it by volume rather than by weight.

Good charcoal is black with a metallic lustre and conchoidal fracture, should give a clear ringing sound when struck, and should burn without smoke and with a clear transparent flame. If the charcoal has been allowed to burn too long in the kiln it becomes deep black and loses its lustre, becoming more porous and lighter: such charcoal takes fire quickly, burns without smoke or flame, and is quickly consumed. If the wood is incompletely carbonised the charcoal has a reddish colour, and gives out much smoke in burning.

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CHAPTER II.

The Manufacture of Turpentine and Colophony.

SECTION I.—GENERAL.

Crude pine resin consists of two principal constituents, oil of turpentine, a liquid, and rosin or colophony, a substacsil solid at ordinary temperatures. These two substances can be separated by distillation under the action of heat, the oil of turpentine being distilled off and the colophony remaining as a residue.

Colophony is used in soap-making, for sizing paper, soldering, in the manufacture of sealing wax, varnishes, cements, and ointments, for mixing with shellac to lower its melting point and for other purposes. Oil of turpentine is largely used in the preparation of paints and varnishes, as well as in medicine: it is also extensively employed for dissolving fats, resins and caoutchouc, and has recently been used as a raw material in the manufacture of artificial camphor.

There are various methods of distilling turpentine oil—both from resinous wood and from the crude resin obtained by tapping trees. In India the process hitherto adopted in resin distilleries has been the primitive water-distillation or furnace heat process, of which a description is given below. In America this process has been discarded in favour of superheated steam distillation, since the latter has been found to produce a better quality of turpentine oil than the former. In India also the primitive furnace heat distillation is also giving place to steam distillation, for at the new resin distillery now being established at Shahdara near Lahore steam distillation will be the process employed, while at the Bhowali distillery, in the Naini Tal Forest Division, a new steam distillation plant is to be erected, to replace the furnace heat plant hitherto in use there.

A description of some of the principal methods of resin distillation will now be given. The method of water distil-

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lation is described in some detail, in spite of its being more primitive and less satisfactory than the more modern processes, because it is the only one which has hitherto been employed in India, and considerable experience has therefore been gained in the details of the process.

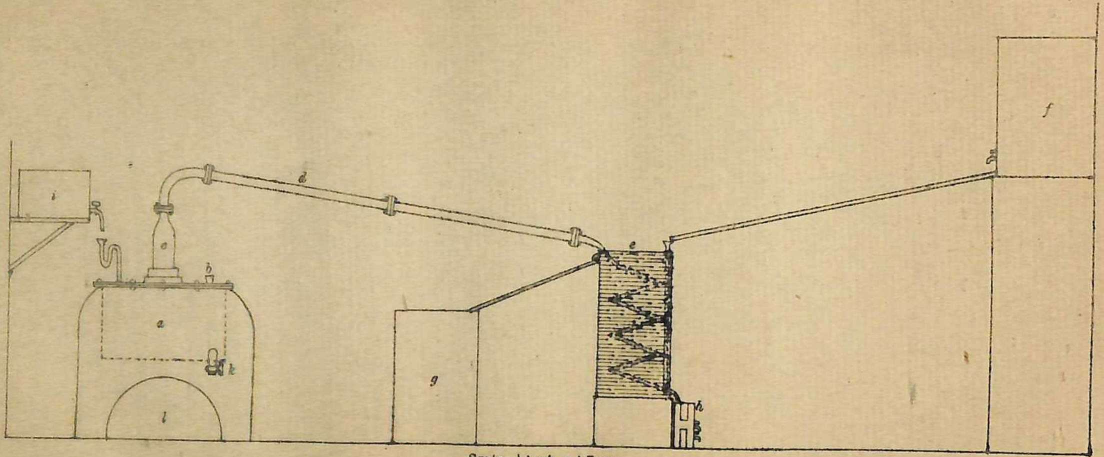
Section II.—Water Distillation.

This process, which is a primitive one, has been employed for some years for the distillation of the crude resin of *Pinus longifolia* at the Bhowali distillery in the Naini Tal Forest Division and at the Kalsi distillery in the Chakrata Forest Division, while it was formerly employed at the Nurpur distillery in the Punjab, prior to its closure some years ago, and at the Dehra Dun distillery before its transfer to Kalsi. Allowing for certain slight differences of detail at the various distilleries, the following description, based mainly on the methods hitherto in force at Bhowali, gives a general idea of the process :—

(1) *Purification of crude resin.*—The crude resin, which arrives from the forest in tins, always contains impurities such as pine-needles, pieces of bark, etc., which require to be removed. The resin is accordingly first heated in large copper pans until it is thoroughly melted, and is then passed through fine wire gauze sieves, the impurities being thus separated.

(2) *Distillation.*—The form of still used is that shown on Plate XXIII. The crude resin, melted and purified in the manner described above, is introduced into the copper boiler *a* through a hole at the top, *b* ; the hole is then tightly plugged, and a fire is lighted in the furnace *l*. At Bhowali 9 kerosene tins (about 36 gallons) of crude resin are used for each distillation, and 2 quart bottles of water are added at the time of charging the boiler. The resin, with the added water, is raised to a temperature of about 150°C. or somewhat higher, when distillation commences. Care has to be taken not to raise the temperature above 175°C. : at higher temperatures not only does the colophony begin to disintegrate, but much of it is mechanically carried over with the oil, besides which the heavier oils are distilled out, vitiating the quality of the turpentine oil. Even 175°C. is a higher temperature than is desirable. Distillation usually commences about ¾ of an hour after the boiler is charged, when water

DIAGRAM OF A SIMPLE TURPENTINE DISTILLERY. (WATER DISTILLATION PROCESS).



Scale—¼ Inch = 1 Foot.

a. Copper boiler.
b. Hole for admitting crude resin, with plug.
c. Dome.
d. Copper pipe.
e. Condensing tanks.
f. g. i. Water tank.
h. Receiver for collecting oil of turpentine.
k. Tap for emptying out colophony.
l. Furnace.

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is turned on, from the tank, *i*, and is allowed to drip steadily through a bent funnel into the boiler during the process of distillation. The steam generated by the heat of the furnace, containing oil of turpentine, passes up through the dome *c* and along a copper pipe, *d*, which terminates in a spiral worm passing through a condensing tank, *e*, through which a constant steam of cold water flows from a tank, *f*, to another tank, *g*. The oil mixed with water, issues from the condenser into the receiver *h*, the oil remaining on the top and the water sinking to the bottom. When the flow of oil into the receiver *h* becomes small and shows signs of ceasing, the water from the tank *i* is shut off; this is very necessary, for if water is left in the colophony the latter becomes opaque. The boiler is then heated up for a few minutes to drive off any water remaining in it, and the fires are extinguished, after which the colophony is passed out through the tap *k* in a liquid state, strained through cloth, and allowed to cool and solidify in large pans.

Where water is not readily obtainable, the water which passes into the tank *g* is allowed to cool and can be used over again. Where a plentiful supply of water is available, and can be laid on by pipes from outside, the two water tanks, *f* and *g*, can both be dispensed with, the water being led straight into the condenser. Care should be taken to heat the boiler gradually at the commencement, otherwise the resin, if overheated, is liable to overflow and choke the condensing pipe; to prevent a similar accident the dome *c* and the perpendicular part of the pipe above it should be not less than 2 feet high.

The dimensions of the still differ according to requirements: the capacities of the stills hitherto used in India have ordinarily varied from 2 to 6 maunds of crude resin, and it has been found possible to work 4 charges per diem, the process of distillation taking 3 hours for each charge. The pattern of the turpentine-receiver varies; in some receivers the turpentine flows off of its own accord into storage tanks, while the receiver shown in the diagram consists of a copper cylinder, with glass on the side, fitted with two taps, turpentine being drawn off by the upper and water by the lower one.

The flat-topped boiler, as shown in the diagram, is open to objection on the ground that the steam containing the oil vapours cannot pass out quickly enough, but striking the top condenses and falls back into the resin ; a dome-shaped top would probably give better results.

At Bhowali 43 quart bottles of turpentine are obtained at each distillation. The last 13 bottles contain impurities, and it has been found advisable to re-distil these in a separate still. One maund (80 lbs.) of crude resin of *Pinus longifolia* produces on an average 1½ gallons of oil of turpentine and ¾ maund of colophony.

(3) *Purification of oil of turpentine.*—The oil of turpentine when freshly distilled is of a milky appearance, owing to mixture with water, and has a somewhat disagreeable odour. This may be attributable to overheating of the stills. The purification of the oil is effected by allowing it to stand in bottles in the sun for about 2 days, when the water separates out in the form of drops on the sides of the bottle ; the liquid is then filtered through blotting-paper, most of the water remaining on the side of the bottle and the remainder being absorbed by the blotting-paper. This procedure is open to the objection that some of the volatile portions of the oil are lost in the process; it would be unnecessary if the oil were rectified by redistillation.

Washing with lime-water purifies the oil by getting rid of the free acids which it contains in its crude state, as well as some of the resinous impurities that are mechanically carried over. Purification of the oil can be accomplished most effectively by redistilling it after washing with lime-water. Rectification by redistillation, however, has never been resorted to in the Indian distilleries.

SECTION III.—STEAM DISTILLATION PROCESSES.

1. *General.*

Water has been used for the distillation of essential oils from ancient times and in the most primitive methods, the water vapour or steam serving to separate the more volatile constituents from the non-volatile materials. The distillation depends on the physical fact that the boiling point of a mixture of two liquids which are not miscible is always lower than the boiling points of either of the two liquids when distilled separately. Water distillation and steam distillation are based on the same principle ; but owing to many defects in water distillation, it has in modern processes

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been universally replaced by steam distillation. The latter is particularly necessary in the case of those materials which are liable to char by coming in contact with stills heated directly by open fire, and in the case of gums and oleo-resins whose products of distillation would deteriorate in quality by over-heating. Turpentine oil, though not a very delicate oil, is nevertheless highly sensitive to heat, and is liable to become heavy owing to overheating in water distillation. The water distillation process is not rapid, nor is it possible to distil by its means a large quantity of the material at a time. In the case of turpentine oil, therefore, steam distillation is a great improvement on water distillation in that the danger of overheating is obviated and operations can be carried out on a much more extensive scale.

Steam distillation has not yet received a practical trial in India, although, as mentioned above, it is being started at Shahdara near Lahore and in the Bhowali distillery in the United Provinces. It would therefore be premature to give here any but a mere outline of the chief processes, based mainly on American experience.

2. *Mixed Method of Distillation.*

In this process the crude resin, placed in a form of steam still set up over a furnace, is heated to about 130°-140° C., when steam is admitted. In this process, steam serves a three-fold purpose, as an agitator, as a disintegrating agent, and as a means of conveying the vapours of the spirits of turpentine to the condenser.

It may be noted here, that if steam is passed without initially heating the crude resin, too much water comes over and very little oil of turpentine, so much so that commercially speaking this method of distillation, that is with wet steam only, is inadmissible: apart from this the yield of oil is extremely poor.

3. *Superheated Steam Distillation.*

This is the most recent method in general use. The crude resin is kept in a steam jacket, that is, a closed space surrounding the still, which has a double bottom and sides; the still is fitted inside with a steam coil. The temperature of the chamber is made to rise to 150° C., by letting in steam into the coil and the jacket at a pressure of four to seven kilograms per sq. cm.: at this temperature the volatile

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top condenses and falls back into the resin ; a dome-shaped top would probably give better results.

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constituents of the resin come over. The vapours are led into a closed hollow cylinder, a kind of tubular condenser in which there are mechanical arrangements for causing a partial vacuum during the process of distillation. This process, therefore, is a combination of vacuum distillation and steam distillation; it is said to produce oil of turpentine of a very good quality.

In another method of distillation by superheated steam the steam jacket is replaced by an ordinary steam still containing crude resin, which is kept hot by means of a closed steam coil heated to 100°C., superheated steam being let in when that temperature is reached. This process is said to be a very rapid one.

4. *Vacuum Distillation.*

A patent has recently been taken out for distilling turpentine *in vacuo*. The crude resin is heated and distilled in a vacuum and mechanically agitated at the same time. The vacuum is produced by suitable pumps driven by engines. The apparatus used for agitating the crude resin has mechanical stirring arms and has its outlet connected with a reflux condenser, so that the heavier volatile substances fall back into the heating chamber, whilst the more volatile constituents pass on to a second condenser. After the material has been sufficiently heated, air is admitted into the apparatus, and the mass is allowed to stand in order to cause the solid impurities to settle, after which the impurities and the water are separately drawn off.

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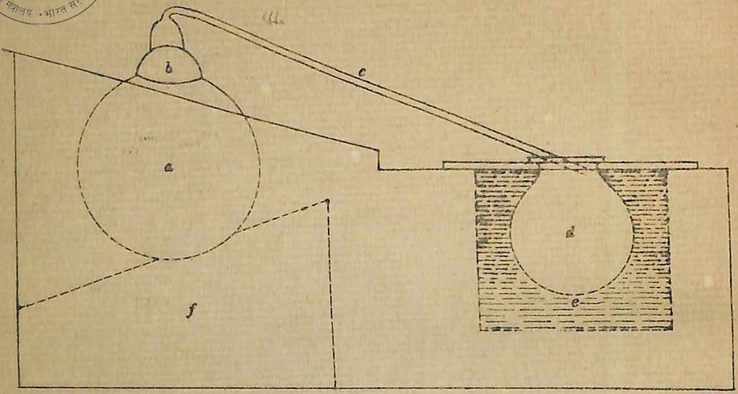
PLATE XXIV.

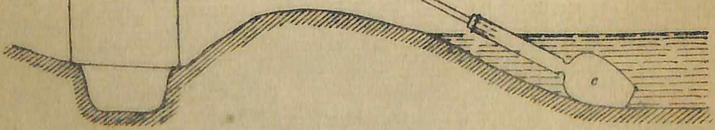
1. SANDAL-WOOD OIL STILL.



Scale—$\frac{1}{8}$ Inch = 1 Foot.

- *a.* Boiler (earthen pot).
- *b.* Small inverted brass pot.
- *c.* Copper tube.
- *d.* Condenser (copper pot).
- *e.* Water-tank.
- *f.* Furnace.

2. RUSA-GRASS OIL STILL.



Scale—$\frac{1}{8}$ Inch = 1 Foot.

- *a.* Boiler (iron).
- *b.* Bamboo tube.
- *c.* Condenser (copper).

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CHAPTER III.

The Extraction of Various Oils and Tars.

SECTION I.—SANDALWOOD OIL.

Sandalwood oil is obtained by distilling by the wet process chips of the heartwood of the sandalwood tree (*Santalum album*), the root-wood being preferred. Although part of the sandalwood oil of commerce is distilled in Europe from wood exported from India, the oil is also locally distilled in some parts of the Madras Presidency, the stills employed being of a primitive kind. There is a sandalwood oil distillery at Mankapur in the Gonda District of the United Provinces, whither the sandalwood is brought all the way from Mysore, fuel being plentiful at Mankapur. The form of still used varies slightly in different places, but the principle of the still is as shown in Plate XXIV, fig. 1: *a* is a large earthen pot placed above a furnace, *f;* into the pot *a* are put about 6 gallons of water and 56 lbs. of fine sandalwood chips, and a small inverted brass pot, *b*, is then placed over the pot *a* and tightly fixed to it by means of clay and cloth.

From the pot *b* a copper tube about 1¼ inches in diameter and from 3½ to 5½ feet in length leads into another copper pot, *d*, of about 3 gallons capacity, which is suspended in a trough of cold water. The mouth of the pot *d* is covered with leaves and coarse grass. When the boiler *a* has been charged the furnace is lit, large fuel billets of above 6 inches diameter being used to produce a strong steady heat; the steam thus generated passes down the pipe and condenses in the vessel *d*, in which the water collects with oil floating on the surface. The oil is skimmed off and collected in another vessel, only a small quantity of oil being obtained each time. In a still of the size here mentioned one boiling takes 21 days, when the boiler is immediately re-charged; the fire is kept burning night and day. As many as a dozen such stills are usually constructed side by side in a line, the whole system of stills being set in mud bricks. The diagram gives the end elevation of such a system of stills, showing a single complete

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still side view. In the Mankapur stills one boiling lasts for 5 days only, and the contents of the condensing vessels, containing water and oil, are emptied daily. There are 2 to 8 condensing vessels to each boiler, and the size of the latter varies accordingly.

Sometimes the boiler has no inverted pot over it, the copper tube leading straight out of a lid fitting tightly to the top of the boiler. In some stills there are two tubes leading out of one boiler, the lower end of each tube fitting tightly into a narrow-necked copper condensing pot, there being thus two condensing pots in each cooling-tank.

The average outturn per annum for a still of the capacity mentioned above is estimated to be about 21 lbs. of oil. The yield of sandalwood oil is generally put down at 2½ per cent. of the wood used.

At Kanauj in the United Provinces, where distillation is extensively carried on, the proportion of oil is stated to be never below 5 per cent. In this case the sandalwood is reduced to a fine powder by filing; this powder is soaked in water for 48 hours and then placed in a still of copper tinned inside. The Kanauj distillers maintain that wood yielding less than 5 per cent. of oil is of inferior quality.

According to Puran Singh,[*] a properly equipped plant for the distillation of sandalwood oil should consist of the following:—

(1) A rasping machine to reduce the wood to fine filings.

(2) An efficient form of steam still complete with tubular condenser, florentine flasks, etc.

(3) A small copper still for re-distillation of the oil.

(4) A boiler capable of generating superheated steam.

Section II.—Deodar Oil.

Deodar oil is obtained by the destructive distillation of chips of deodar wood. The chips are placed in an earthen vessel with a narrow mouth, which is inverted into an empty vessel with a broad mouth. Fire is then applied round the vessel containing the chips, and the oil trickles down into the lower vessel: sometimes the chips themselves are lighted inside the inverted vessel, this causing the expulsion of the oil. The oil obtained by this primitive method is by no means pure, being mixed with acids and tarry ingredients.

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[*] Forest Bulletin No. 6, 1911.

SECTION III.—PINE AND TEAK TAR.

Tar may be obtained from any species of pine, the chief species employed in India being *Pinus longifolia.* There are two principal methods of manufacture. In Jaunsar the method employed is as follows:—A kiln is built of stones and mud-mortar, the inside, which is egg-shaped and tapers towards the bottom, being faced with lime: the internal dimensions are height 5 feet and maximum diameter also 5 feet. At the bottom is a perforated iron plate, while at the top is an opening 2 feet in diameter. Pieces of pine wood 1 to 2 feet long and 4 to 6 inches in girth are introduced through the upper opening and packed as tightly as possible inside; the opening is then closed with stones and mud, except for three small holes to admit air. The wood is lit from the top and burns downwards, the rate of burning being regulated by closing or enlarging the holes. Crude tar mixed with acids drips through the perforated plate and is collected in tins placed below, charcoal remaining within the kiln. The burning takes about 9 days to complete, the charge of 15 maunds of wood producing $1\frac{1}{5}$ maunds of tar and 6 maunds of charcoal.

The second method, which does not produce so much tar and charcoal per unit of wood, is as follows:—Dry chips of wood are placed in an earthen pot, in the bottom of which a few small holes have been drilled; the mouth of the pot is then closed with clay, and the pot is placed over a smaller pot which has been placed in a hole in the ground, the joint between the two pots being then tightly luted with clay. Fire, usually of cowdung, is applied round the upper pot and kept burning for 8 or 9 hours, the tar dripping through the holes into the lower pot and charcoal remaining in the upper one. It is preferable to have two or three sets of pots close together and one fire applied round the whole; by this means the cost is considerably reduced.

Pine tar is used in India for tarring bridges, posts, roofs, etc.; by itself it is somewhat thin and liable to wash off, and usually requires to be mixed with one-third coal tar,

Tar can be obtained from teak by the same methods and is used for the same purposes, and also for anointing sores on buffaloes.

SECTION IV.—OIL FROM OIL-GRASSES.

1. *Rusa-grass Oil.*

The distillation of Rusa-grass oil, from *Cymbopogon Martini*, is carried out in various parts of Central India by a method of wet distillation similar in principle to that employed for the distillation of sandalwood oil, the chief points of difference being that in the distillation of Rusa-grass oil an iron boiler and a bamboo tube are employed in place of an earthen boiler and a copper tube, while the condenser is placed in a stream instead of in an artificial water trough.

The oil is distilled chiefly from the flowers, the best season for collecting being from the middle of September to the end of October. The flower-stems are cut to a length of about 1½ feet from the top, so as to obtain only the flowers and a few of the upper leaves, and those which cannot be immediately distilled are tied in small bundles and dried, in the shade if possible, and stacked near the still. Distillation is carried out from the middle of September to the end of December. The distilling apparatus (*vide* Plate XXIV, fig. 2), consists of an iron boiler *a*, varying in capacity, into which the grass is tightly packed, water being added in the proportion of about 45 gallons of water to 100 lbs. of grass; the lid, a flat disc of iron or wood, is then fixed tightly to the mouth of the boiler by a luting of pulse flour, the lid being held down by iron clamps or weighted with large stones. In the centre of the lid is a round hole about 1½ inches in diameter, through which the bamboo tube *b* is admitted. This bamboo distilling-tube consists of two parts, an upright piece, about 1½ feet long, fitting into the boiler and a long piece, varying from 6 to 8 feet in length, fitting into the condenser *c*. These two parts of the tube are firmly fixed together at an angle of about 75° by the aid of a wooden peg and a tight binding of cloth and string. Both parts of the tube are tightly bound round with string throughout their whole length, except for about 6 inches at the end which is fixed into the boiler, and another 6 inches at the end which is fixed into the condenser: this binding gives strength to the tube. Where the string binding ceases at the condenser end a shoulder of rag and string is bound round the tube to act as a stopper. The condenser *c* is a copper vessel with a long narrow neck about 2 feet in length into which the bamboo tube is fixed tight by the cloth stopper. The condenser is placed in a stream of water, the upper part of the neck projecting above the water.

When the boiler has been charged with grass and water a fire is lit below it, the steam generated passing along the tube into the condenser, where it condenses into water mixed with a small quantity of oil. After a period varying from 2 to 4 hours no more oil is obtained, and the condenser is detached from the tube. To separate the oil from the water one method is to pour the contents of the condenser into a circular basin and stir the liquid round rapidly with a spoon: the oil then collects in the vortex formed in the centre, and can with care be skimmed off quite pure. Another method of separating the oil is to fill the condenser up to the brim with water, when the oil rises to the surface and can be scooped out.

The Rusa-grass loses about 40 per cent. of its weight in drying: it is estimated that 100 lbs. of dry grass with 45 gallons of water will produce on an average 12 ounces of oil. The oil constitutes about 1 per cent. of the distillate collected in the condenser.

2. *Lemon-grass Oil.*

The industry of distilling oil from the lemon-grass (*Cymbopogon citratus*) is a long established one in Travancore, where the following method of distilling the oil is employed:—

The grass is cut a few inches above the root-stock, and is then cut into lengths of about 2 feet to enable it to be packed easily into a copper boiler, which is about 10 feet high and 4 feet in diameter, and holds about 120 cubic feet of grass. Water is added, and the top of the boiler is closed. A conducting pipe leads from the top of the boiler to a wooden condensing vessel, to which cold water is constantly supplied; after coiling several times through the cold water the pipe leads out and the condensed mixture of oil and water is discharged into a tin vessel, the oil being afterwards skimmed off the surface of the water. The oil, after separation, is gently heated in order to get rid of any surplus water. The whole process takes 24 hours, and at each distillation 1½ bottles or 36 ounces of oil are produced.

CHAPTER IV.

The Distillation of Camphor.

SECTION I.—GENERAL.

Camphor, like other essential oils, may be distilled either by steam or with the aid of water. Experiments have recently been made to ascertain the possibility of distilling *Ngai* camphor from *Blumea balsamifera* on a commercial scale, but so far these experiments tend to show that the camphor content of this plant is too low to admit of camphor extraction on a profitable scale. Apart from this, *Ngai* camphor is not a true camphor, and a further process of chemical oxidation has to be carried out to convert it into common camphor.

In the case of camphor yielded by the camphor tree, *Cinnamomum Camphora*, the wood, which contains 3 to 4 per cent. of camphor and oil, is first reduced to small chips. Camphor is also yielded by the leaves and twigs of this tree, while in old trees it is, at times, found in a crystalline condition in cavities in the trunk. The actual distillation may be carried out in different ways, some of which will now be described.

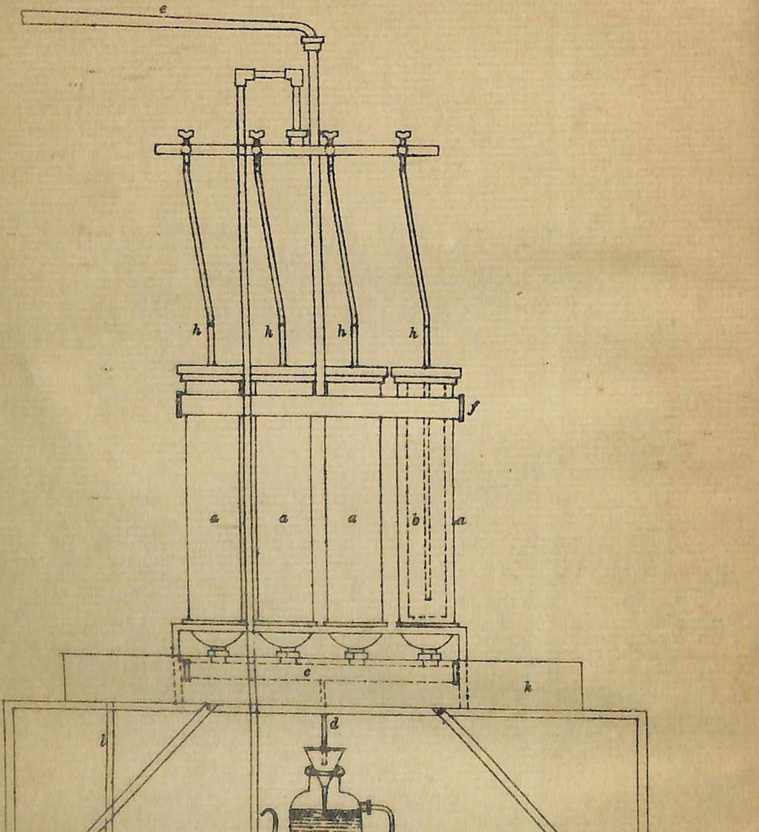
SECTION II.—DISTILLATION BY PRIMITIVE METHODS.

In the Chinese method of distilling camphor, chips of camphor-wood, or leaves and stems of *Blumea*, as the case may be, are packed in a bamboo woven cylinder which is then placed in a cauldron filled with water on bamboo batons a few inches from the bottom. On the top of the cylinder rests a similar cauldron filled with cold water, which is baled out frequently and replenished in order to keep the temperature as low as possible. The steam rising through the chips of wood or leaves extracts the camphor and deposits it on the bottom of the cold cauldron, from which it is scraped off periodically.

PLATE XXV

CONDENSER FOR CAMPHOR DISTILLATION.

Scale $\frac{3}{4}$ Inch = 1 Foot.



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Another crude method is to distil the chips of wood in water, the distillate passing off through straw or small twigs, on which the camphor sublimes, coating them with whitish crystals; the camphor is then scraped off and the oil is pressed out of it.

In the Japanese method of distillation the condenser consists of a long wooden box with a number of parallel wooden partitions, the vapour from the boiler passing from one chamber to another through holes in alternate corners of each partition. The box is placed with its open side resting on a tank of cold water, and the camphor sublimes on the wooden partitions.

SECTION III.—STEAM DISTILLATION.

The condenser shown in Plate XXV, which was designed by Mr. Puran Singh, is reported by him to have proved satisfactory for the distillation of camphor. The distillation is carried out in an ordinary steam still; the steam from the boiler passes through the steam still containing the raw material and, charged with camphor and oil, enters the condenser by the pipe *e*. The condenser consists of four zinc cylinders, *a*, with similar but smaller concentric cylinders, *b*, screwed into each; these inner cylinders are closed at the bottom. The outer cylinders, *a*, are set in a copper tube *c*, which is held fast in a metallic frame, and has an exit tube, *d*, fitted to its under side, opening into a Florentine flask *i*. The steam entering the pipe *e* passes along a copper tube *f*, from which it enters the cylinders *a* by openings in their sides. Cold water is supplied through a pipe *g* and enters the four inner cylinders *b* by means of the pipes *h*, which are fitted with taps; on filling these inner cylinders the water overflows all round the outer surfaces of the cylinders *a* through small holes bored in these cylinders round their top edges, into the tank *k*, whence it drains away through the pipe *l*. The steam in the spaces between the inner and outer cylinders deposits camphor on the surfaces of the former, the outer surface of *b* being considerably cooler than the inner surface of *a*. The condensed steam, containing oil, flows down through the tubes *c* and *d* into the Florentine flask *i*, where the oil separates from the water.

CHAPTER V.

The Manufacture of Cutch and Kath.

SECTION I.—GENERAL.

There are three different substances obtained from the heartwood of *Acacia Catechu*, and also from the less common *A. Suma*, known as (1) *Cutch*, or so-called dark catechu, of a rusty brown or dull orange colour, a brittle texture, and with a shining fracture, (2) *Káth* or *Kátha*, a grey-coloured crystalline substance, and (3) *Keersal*, a pale crystalline subtance occurring as a deposit in the heartwood, and obtained from cavities in the wood.

Cutch, which is an important commercial product and is largely exported, is used as a dyeing agent, being much employed for dyeing canvas a brown colour, and for dyeing fishing-nets, to which it acts as a preservative ; as a tanning material it is not satisfactory, as the leather produced is apt to give a yellow stain. Cutch is also extensively used in medicine as an astringent. *Káth* is used for eating with *pán*, and is sold in bazars for this purpose : it is not exported. *Keersal* is much valued as a medicine by the Hindus.

Cutch and káth are both obtained by boiling down chips of the heartwood of *Acacia Catechu*. Cutch contains two distinct substances, a variety of tannic acid called mimotannic acid or catechu tannin, which is soluble in water, and catechin or catechuic acid, which is insoluble except in hot water : the two substances are present in about equal proportions. Káth consists chiefly of catechin, obtained by removing the tannic acid from the mixture : káth as ordinarily prepared, however, consists by no means of pure catechin, though it may be termed a form of crude catechin.

SECTION II.—PREPARATION OF CUTCH.

The methods of preparing cutch differ locally, but perhaps the most general method of manufacture is as follows :—

The heartwood, preferably that containing a quantity of the white deposit alluded to above as "keersal," is cut into small chips, which are boiled in water for about 12 hours in earthen pots, by which time the water is reduced by about one-half. The liquid is then poured off into a large iron cauldron and further boiled and stirred until it attains the consistency of syrup, after which it is poured out into wooden frames lined with leaves and allowed to cool, when it hardens into brick-like masses. In some districts the liquid, after boiling several hours, is poured over fresh chips and again boiled. It is estimated that the weight of cutch yielded varies from 3 to 10 per cent. of the weight of wood used. In Burma cutch was formerly adulterated with extracts of the barks of various species of *Terminalia*, but this has been made illegal.

SECTION III.—PREPARATION OF KÁTH.

The preparation of káth is similar to that of cutch in its first stages, but the subsequent operations vary in different localities. The chips are boiled and the liquid re-boiled with fresh chips until it becomes thick, when it is poured into moulds dug in fine dry sand, which absorbs much of the tannin in solution, the catechin crystallizing out. Another method is to pour the thick extract into a wooden trough made of *Moringa* or *Bombax malabaricum*, adding a small quantity of castor-oil seed : after remaining in the trough for about twelve hours until it has attained a jelly-like consistency, the extract is thrown into a hole dug in the ground, where it remains for about two months, after which it is spread on sand, cut up into small bricks, and sold.

Káth-boilers are careful to select only trees whose heartwood contains spots of white deposit; this they do by cutting into the heartwood and leaving the tree for several hours, after which the spots, if present, become clearly visible. Dead trees show the spots at once if they exist. Iron cauldrons are carefully avoided in the preparation of káth, as the iron destroys most of the catechin.

SECTION IV.—IMPROVED METHODS OF MANUFACTURE.

The local methods of manufacturing cutch and káth are extremely wasteful, as a large quantity of the tannin and catechin remain in the chips after boiling, owing to the size of the chips: also the káth as usually manufactured contains

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a large proportion of sand owing to the crude method employed in filtering off the tannin. Experiments by Dr. Leather have led to the following conclusions:—

(1) The wood, instead of being chipped, should be shaved fine with a plane, and the shavings used for boiling, as the amount of extract obtained from shavings is more than three times that obtained from an equal weight of wood. Sawdust produces nearly as much extract as shavings, but it is difficult to separate it from the distillate after boiling. (2) Large quantities of water are unnecessary for boiling the wood, as the water has to be evaporated, causing much waste of fuel; it is hardly necessary to employ more than 10 parts of water by weight to one part of wood. (3) It is not necessary, if shavings be employed, to boil for more than half an hour, as compared with the long period of boiling occupied under the ordinary methods of manufacture.

Dr. Warth had previously recommended that the manufacture of tannin and catechin should be carried out simultaneously by producing shavings by machinery, boiling them in 20 times their weight of water for half an hour, and leaving the extract thus obtained to cool; the catechin is thus precipitated, and the liquid portion is got rid of in a filter press, the residue in the filter, as well as the liquid, being then evaporated in vacuum pans to hasten drying, the liquid yielding the tannin and the residue the catechin.

By means of the filter press and drying in vacuum pans the time taken to separate the catechin is hastened. This is of importance, as catechin decomposes quickly if kept in solution, and although it is insoluble in water at ordinary temperatures it takes a long time to precipitate in a solution containing so much tannin. By means of these improvements in manufacture trees ordinarily rejected by káth-boilers can be utilized, as cutch and káth can both be obtained from wood containing no white deposits. By utilizing shavings instead of chips the yield of extract (including tannin and catechin) obtained in the various experiments made has been $14\frac{3}{4}$ to 24 per cent., most being obtained from wood with white spots. With chips, from $2\frac{1}{2}$ to $4\frac{3}{4}$ per cent. of extract was obtained in similar experiments. The percentage of catechin to wood varied, in these experiments, from nearly $6\frac{1}{2}$ to 9 when obtained from shavings, and from under 1 to $1\frac{3}{4}$ where chips were used. An analysis of bazar káth gave under 60 per cent. of catechin, the remainder consisting of tannin and sand.

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CHAPTER VI.

The Preparation of Tannin Extracts.

SECTION I.—GENERAL.

Bark and wood for tanning purposes are bulky articles to transport to a distance, and hence certain methods have been devised for preparing tannin extracts from them ; these extracts have the advantage, not only of portability, but also of shortening the process of tanning to a few weeks, as compared with the old system of stratifying hides alternately with layers of ground bark, a process which took from one to two years. In establishing a factory for preparing tannin extracts proximity to the forest is a great advantage, in order to minimize the cost of transporting bark and wood.

It is also necessary to have a good supply of cold water at say 15° to 20°C.

SECTION II.—THE PROCESS OF MANUFACTURE.

The main principles in the manufacture of tannin extracts are simple, and consist of the following steps :—

(1) *Extraction.*—The wood or bark is chopped into small pieces, this being done on a large scale by special machinery. The chips are then subjected to the action of hot water in order to extract the tannin, distilled water being used. The extraction or "leaching" is carried out either at ordinary atmospheric pressure in a system of wooden vats, or under pressure in a battery of closed copper autoclaves ; the former method is generally considered more satisfactory. The "leaching" is done at different temperatures, according to the materials treated, but generally a temperature of 70° to 80° C. is sufficient. In order to extract all the available tannin the materials should

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be leached 4 to 7 times, the richer tannin materials, like mangrove barks and myrabolans requiring longer leaching than those poor in tannin.

The tan liquors are concentrated by passing them through a series of wooden vats filled with raw material till they show a specific gravity of 9 to 11 Beame, and the concentrated liquors are next transferred to a large tank made of wood or copper, known as the "liquor tank."

(2) *Cooling.*—After extraction, the tan liquors are cooled to 18°C. or slightly under; according to recent experience, tubular refrigerators are found to be the most satisfactory.

(3) *Filtration and clarification.*—A good deal of clarification is effected during the cooling process, during which some insoluble substances are precipitated. In order to complete the clarification the liquors are filtered through filter presses or decanting centrifugals, or may be allowed to stand in large decanting vats in order to deposit their insolubles.

(4) *Evaporation.*—The clarified liquors are next evaporated in vacuum pans into solid extracts. Evaporation cannot be done at the ordinary atmospheric pressure, since prolonged boiling destroys tanning matter by oxidation.

(5) *Decolorisation.*—The chief decolorising materials employed are (1) sulphurous acid or bi-sulphites, (2) blood or albumen, (3) oxalic acid and alumina, (4) animal charcoal, (5) haloid salts or organic acids, (6) sulphurous acid gas under pressure, (7) aluminium hyposulphite, (8) barium chloride, (9) lead nitrate, and (10) lactic acid. All chemical processes of decolorisation, however, entail some loss of tannin, and some of them affect injuriously the quality of the extracts. For this reason the expert tanner endeavours to obtain colourless leather not by decolorising the tannin extract but by making a judicious mixture of tanning materials of different colours. Thus in India the bark of babul (*Acacia arabica*), which is decidedly the best tanning material, is never used alone, as it gives leather a red colour, but is

mixed with myrabolans in suitable proportions, the result being a colourless leather, suitable for taking the most delicate shades of aniline dyes. In this way many different kinds of tanning materials may be utilized for the manufacture of extracts of standard colour and strength.

Section III.—Factors affecting the Quality of Tannin Extracts.

There are certain factors which affect the quality of tannin extracts adversely or otherwise. The chief of these are as follows:—

(1) *The quality of the raw material.*—The fresher and sounder the bark, wood, or other raw material used the better is the quality of the resulting extract. If the bark is exposed for any length of time to atmospheric oxidation through rain, air, or sunshine, the tannin in it becomes oxidised, resulting in a darker colour. It is therefore necessary always to secure a regular supply of fresh materials. For this reason it is most desirable that the central factory should be situated close to the sources of supply, while the raw material, if it cannot be made use of immediately, should be air-dried in well ventilated sheds.

(2) *The quality of the water used.*—It is well known that mineral matters present in natural waters, when used for the extraction of tanning materials, have an injurious effect on the colour and percentage of tannin in the resulting extract, on the colour particularly when it is alkaline in reaction or when it has traces of iron in it. The loss of tannin is due to the formation of non-tannins and in some cases of alkaline tannates. This process of decomposition of tannin set in by the mineral matter does not cease after the extracts have been prepared in the solid form. The saline matters even after extraction go on accentuating still further the loss already incurred during preparation, whether they do so by actually precipitating out the tannin by their

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contact or by inducing its conversion into non-tannin. In any case, the consequence is that the tannin extract prepared by saline waters will not only show loss of tannin during the process of manufacture, but will continue to do so even during subsequent storage.

Besides this chemical decomposition, if the water used is, in its concentrated state, at all alkaline, it will darken and deepen the red colour of the extract. It is therefore essential that distilled water should always be used in the manufacture of tannin extracts: the tan-liquors when they are evaporated in vacuum-pans would yield distilled water for this purpose at no additional cost if a suitable condenser were attached to the vacuum-pans to condense the vapours and recover the condensed water.

(3) *Iron contact.*—Great care should be exercised in avoiding the contact of tan liquors with iron in any shape, as this causes the blackening of the extract. One of the chief causes of the blackening of tannin extracts has been neglect of this factor.

(4) *Atmospheric action.*—The tan liquors should not be allowed to stand exposed for any length of time to atmospheric action. As soon as they are concentrated enough, they should be subjected to cooling, filtration and evaporation as described above.

(5) *Heating* of tan liquorsfor a longer time than is absolutely necessary is another factor which has a very detrimental effect in causing the decomposition of tannin extracts owing to the formation of non-tannins and oxidation products.

(6) *Storing* for any great length of time, even of good extracts, results in the reduction of their tannin strength. It is due to slow oxidation resulting in the formation of insoluble products.

CHAPTER VII.

The Manufacture of Paper-pulp.

SECTION I.—GENERAL.

The chemical and mechanical operations employed in the art of paper making may be divided into two sections, of which the first is a process of tearing down, that is the preparation of cellulose from the raw materials, known as pulp making, and the second one of building up, that is the elaboration of this cellulose into paper. When the chief raw materials were rags and the waste of textile factories, both these operations were combined in one factory, but with the introduction of wood-pulp it was recognised that the division of labour, by which the pulp maker carried out his operations in or near the forests which supplied his raw material, while the paper maker performed his share of the manufacture in or near the large centres of consumption and distribution of paper, resulted in greater efficiency and economy. It is this division of the industry which has so largely reduced the cost of paper during the last thirty years. By it, the bulk of the waste, amounting to 50 to 60 per cent. of the raw wood, is eliminated at its source, and the subsequent freight and handling charges to the paper factory are incurred on a partially manufactured material which yields 90 to 95 per cent. of paper. Formerly, when the paper maker collected and handled the raw material himself, he had to pay these charges on about 2 tons for each ton of paper produced.

Paper making proper is never likely to become, to any extent, a forest industry. The many hundreds of varieties of paper which can be made from cellulose necessitates the mills being placed where they are in touch with a market continually varying in its requirements and demands, and such positions are usually many hundreds, or even thousands, of miles from the forests and waste lands which provide the raw material. This branch of the subject, therefore, need not be further referred to in this work. Pulp making, on the other hand, is undoubtedly a forest industry, and one likely to show a large expansion in the future, especially in the tropics, where raw materials are found growing under conditions conducive to rapid natural reproduction, thus eliminating a serious difficulty which the industry is now feeling the effects of in its original home, *viz.*, that of cutting out its supplies faster than they can grow.

In 1909 the world's total consumption of paper was estimated at 8,000,000 tons, of which 6,500,000 tons were produced from wood. Its normal growth is estimated at 25 per cent. in ten years, so that in 1919 the total may be expected to amount to 10,000,000 tons, and in 1929 to 12,500,000. But this takes into account the normal expansion only, and does not include that due to the rapid creation of a reading and writing public brought about by the introduction of education into a people or community hitherto illiterate. An example of this is found in England in the years immediately following the passing of the Education Act of 1870, when the consumption doubled and trebled within a few years. In the opinion of many observers, the present sources of supply, namely the spruce and pine forests of Europe and North America, cannot provide any longer for even the normal increase of consumption, still less for any such abnormal expansion as that above referred to; moreover, there are already difficulties regarding the maintenance of the present supply, and it seems inevitable that the industry will ere long be forced to migrate to the tropics to sites where the natural reproduction of the raw material is such that a mill will have a perpetual supply at its own doors. On pages 103 and 207 lists are given of Indian forest products which have been found suitable for pulp making. The list is by no means complete, as the enquiry into the subject is only in its infancy, and the list is continually being extended.

The manufacture of wood-pulp falls into two main divisions in accordance with the processes employed for the reduction of the raw material. One is known as mechanical wood-pulp, the other as chemical wood-pulp. While both are entitled to the designation "pulp," only the latter can be regarded as pure cellulose, the former being merely a loose fibrous mass produced by the attrition of a revolving grindstone upon billets of wood pressed against it. Mechanical pulp therefore contains all the elements of the wood, ligneous as well as cellular, the latter being still incrusted and permeated by the former; it therefore possesses little or no "felting" power, that is, the property of "spin" or "grip" which enables pure cellulose fibres floating freely in water to seize hold of their neighbours and to interweave and interlace themselves with them into the felted fabric we know as paper. Hence it is of inferior value, and cannot of itself make a useful paper; it is, however, less costly to manufacture than chemical pulp, and for this reason alone it finds a large use in the composition of cheap newspaper and similar qualities which are not intended to be preserved, after printing, for any length of time. A fair newspaper quality can be made with mechanical pulp mixed with chemical pulp, in the proportion of about 3 to 1.

Chemical pulp, on the other hand, is a nearly pure cellulose from which all the incrusting ligneous matter has been removed by the action of chemical solvents. Compared with mechanical pulp, which is harsh and brittle, it is soft, pliable and silky; the individual fibres are capable of floating independently of each other in water, and when floated in a thin stream on to the wire cloth of a paper machine and subjected to a slight but rapid transverse shaking action, they interweave with each other in the manner already referred to.

SECTION II.—MECHANICAL WOOD-PULP.

The wood most in favour for this branch of the industry is spruce, mainly because (1) it is white, (2) it is soft, and (3) its fibres (tracheids) are longer than in most of the conifers. With a process of manufacture which, compared with the chemical method, must necessarily produce a harsh pulp, depending for any strength it may have upon the length of its fibres rather than on their felting power, and which has no means of improving on the natural colour, it will be evident that the advantages of spruce over a shorter-fibred, harder and darker-coloured wood are very considerable. The logs when received at the mill are first cut into lengths of 1½ to 3 feet and the bark is carefully removed by hand or machine. Knots are also bored out, and if the diameter of the pieces is too great for the "pockets" they are split into suitable sized billets. These are then placed in the pockets of the grinders, which are receptacles constructed in the iron casing of the grinder for the purpose of holding them in position with one end in contact with the grinding surface. To the other end of the billet hydraulic pressure is applied, so that the billet is pressed and pushed strongly against the stone. The stones vary in size from 48 to 60 inches in diameter and from 18 to 27 in breadth, and revolve at a speed of 150 to 180 revolutions per minute. Each stone has from three to five pockets arranged around its periphery. The action produced by the contact between stones and wood is a tearing rather than a grinding one. The fibres, or rather fibrous bundles, as they are torn off, are instantly swept away by a stream of water which plays on the grinding surface and which also serves to convey the pulp to the sorting screens, which allow the finer particles to pass but retain all the coarser ones. The latter are afterwards reduced to a sufficiently fine condition by treatment in a "refiner," consisting of two stones arranged exactly as are those of a wheat or rice grinding mill. The coarse pulp is fed into these at the opening in the centre of the upper one, is ground between them as they revolve on each other, and finally passes out between them at the periphery. The pulp is then passed on to the water extracting machine, which consists essentially of a drum covered with wire cloth and revolving in a vat to which the stream of pulp is fed, in which it is immersed to $\frac{2}{3}$ or $\frac{3}{4}$ of its diameter. The water passes through the wire cloth to the interior of the drum and escapes at one end, leaving on the wire cloth surface a thin film of pulp which is licked off by an endless blanket or felt pressed by revolving rollers on the upper or dry portion of the drum. The thin sheet of wet pulp is thus transferred to the felt by which it is carried through squeezing rolls, from which it is finally transferred to hydraulic presses. From these it comes out in thick sheets containing about equal weights of pulp and water, and in this condition it is exported to the paper mills, although in some cases it is reduced to a dry state by hanging the sheets in steam heated rooms.

It will be readily understood that a process such as that outlined above must consume a large amount of power. As a matter of fact it does do so more, probably, in relation to its output than in the case of any other manufacture. A mill producing 4 tons air-dry pulp per 24 hours requires an effective power of not less than 300 H. P. It follows therefore that water power is an absolute necessity for economical working. In India the raw materials most suitable are the mountain conifers, and especially the Himalayan spruce, *Picea Morinda*, which has both a good colour and great length of fibre, the latter exceeding that of any of its allied species in Europe or America. Where supplies of it can be found in the neighbourhood of rivers which can be utilized

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not only for power but to float the logs down from forest to mill, there would appear to be good opportunities for the introduction of this branch of the wood-pulp industry.

SECTION III.—CHEMICAL WOOD-PULP.

1. *General.*

The essential difference between chemical and mechanical pulp is that practically the whole of the pectous and ligneous matter permeating and incrusting the fibrous matter of the cells is removed by chemical solvents, the resultant product containing 94 to 97 % of pure cellulose. The processes adopted are three in number, the *Sulphite*, the *Soda* and the *Sulphate*. These all produce satisfactory pulps, and at nearly equal cost, the choice of process to be adopted depending mainly on the kind of wood to be dealt with, the facilities for obtaining the different chemicals required, and the quality of paper for which the pulp is intended. The sulphite process does not eliminate resin, and therefore produces a rather harsh pulp of a pale straw colour, which is difficult to bleach to a pure white. It is therefore used mainly for newspaper, for which its natural unbleached colour is good enough, and, because of the colour and resin difficulty, spruce wood, which has a good colour and little resin, is generally used. Both the soda and sulphate processes get rid of the resin, and therefore produce softer and more pliable pulps, and they also deal more successfully with woods whose natural colour is darker than spruce. With both, the *unbleached* colour is much darker than that by sulphite and is, in fact, more or less brown, but this brown shade is more easily bleached to a pure white than the pale yellow of unbleached sulphite pulp. Hence these pulps are largely used for high class printing and writing papers, on account of colour and softness. Of the two the sulphate is the softer and more easily bleachable.

With all these methods the preliminary operations of barking and reducing to small chips is the same, the only difference being that resinous knots must be bored out for the sulphite process, though they may be left in for the other two.

2. *The Sulphite Process.*

The digesting liquor is bi-sulphite of lime or magnesia or a mixture of both, prepared by burning sulphur in a retort

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from which the resultant sulphur dioxide gas is led off and allowed to pass upwards through towers filled with lumps of limestone, either calcium limestone or the variety known as dolomite, which also contains magnesia. Bi-sulphite of lime or magnesia is thus formed on the surfaces of the lumps; this is washed off continuously and brought into solution by a thin stream of water flowing downwards and trickling over the lumps. This solution is the digesting liquor, and contains both bi-sulphite and free sulphur dioxide. An alternative method of producing it is to suck the gas through a series of tanks filled with milk of lime formed by dissolving *burnt* limestone (quicklime) in water.

The wood chips are filled into steel or iron digesters capable of holding from 5 to 20 tons. Liquor is then poured in until the charge of chips is covered, the digester is closed steam tight, and steam is turned in until a pressure of from 20 to 60 lbs., corresponding to temperatures of from 126 C to 150 C, is reached; this pressure is maintained until the solution of the incrusting matter is complete. The digested material is then discharged from the digester, drained and washed until free from all traces of the liquor and its soluble contents, run through screens or strainers to take out chips which have escaped complete digestion, and finally run over a machine which extracts the water, dries the pulp, and delivers it as thick dry sheets.

As the digesting liquor has a strongly corrosive effect on iron, it is necessary for the digesters to be lined with lead or with non-corrosive cement or tiles. This, and the frequent repairs of these linings, forms no small part of the cost of production, and to some extent counterbalances the lower cost of the liquor as compared with soda or sulphate liquors. It should also be observed that the manufacture of a good liquor depends on the absorption by water of an extremely volatile gas, and the difficulties of obtaining it are largely increased by any rise in the temperature of both air and water over those normal to a cold or temperate climate. For this reason it is considered doubtful whether the sulphite process can be a success in the tropics.

3. *The Soda Process.*

With both this and the sulphate method all the preliminary operations and the final one of turning the pulp into dry sheets are similar to those described under the sulphite process. The chief difference is in the digesting liquor, which in this case consists of caustic soda. As this has no corrosive effect on iron it is not necessary to protect the interior of the digesters. The temperature and the pressure are usually carried higher than in the case of sulphite (to 180° C and 130 lbs.). An important feature of this method is the recovery and re-employment of soda from the waste liquor. This is effected by evaporation to a thick syrupy mass which is finally calcined, the ligneous matter extracted from the wood being burnt off; the residue is carbonate of soda. This is then regenerated into caustic soda by being boiled in solution with quicklime, the liquor thus obtained being the digesting liquor. A certain loss, amounting to from 10 to 20 per cent., occurs; this is made up by the addition, when causticising, of fresh carbonate of soda. The cost of digesting is thus largely reduced.

4. *The Sulphate Process.*

The only difference between this and the soda process is that the loss on recovery of soda is made good with sulphate of soda instead of carbonate. During the calcining process this is reduced to sulphide of soda, and the final liquor after causticising with lime is mainly a mixture of caustic and sulphide. Sulphide of soda has a strongly solvent effect upon organic colouring matter, and the chief difference between sulphate and soda pulp is that the former is lighter in colour and more easily bleachable. The process is also slightly cheaper, as sulphate of soda is less costly than carbonate. The drawback of the process is the strong odour of sulphuretted hydrogen given off, which is sufficient to constitute a nuisance in thickly populated districts.

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CHAPTER VIII.

The Antiseptic Treatment of Wood.

SECTION I.—GENERAL.

When durable woods are not available in sufficient quantity it is necessary to employ less durable woods, which, however, can be treated by one of several processes in order to render them more durable.

Such antiseptic treatment of wood is perhaps of more importance in the case of railway sleepers than for any other class of timber, but it can be applied to piles, bridge and house timbers, telegraph-poles, and any other class of timber where durability is specially required. If suitable and sufficiently cheap methods of rendering timber more durable were introduced into India on an extensive scale, the results would be of great benefit, as large quantities of wood at present considered unsuitable for railway sleepers could be made durable enough to serve their purpose as such.

The methods of rendering wood more durable may be broadly divided into two totally different classes: (1) by injecting an antiseptic solution into the timber after removing the sap, (2) by retaining the sap and converting its component materials, through heat, into antiseptic substances, without the addition of any foreign substance; this process is known as Haskin's process.

SECTION II.—ANTISEPTIC TREATMENT BY IMPREGNATION.

1. *Substances Employed.*

A number of different substances have been tried from time to time, but those which have been most generally employed are the following:—

(1) *Sulphate of copper.*—Impregnation with this substance is known as the Boucherie process, having been first employed

on a large scale in France by Boucherie. The chief advantage of this method is its cheapness. The wood is rendered harder, though more brittle and weaker. The sulphate of copper is apt to become easily washed out of wood exposed to rain or other water, while it acts on any iron bolts or fastenings with which the timber is brought in contact unless the iron is galvanized. On account of these drawbacks the sulphate of copper injection is not so largely employed now as it was formerly.

Impregnation with sulphate of copper was tried in Madras in 1865-66, sleepers of 44 different kinds of local woods having been experimented with: the engineers, however, reported that the strength and durability of sleepers was lessened rather than increased by the process, which was thereupon discontinued. In 1866 some deodar and *Pinus longifolia* sleepers were impregnated in the Punjab, but the results have not been recorded, though the sleepers were reported to be good four years later, a natural result, in the case of deodar at least, whether they were impregnated or not.

(2) *Chloride of zinc.*—Injection with this salt is known as burnettising, the process having been patented by Sir W. Burnett in 1838. Chloride of zinc is a very cheap substance, and does not corrode iron, but, like sulphate of copper, it is apt to be washed out of the wood treated with it: to prevent this glue may be added to the solution which is forced into the timber, a solution of tannin being afterwards injected, so that the glue is converted into a leathery substance which fills the pores of the wood and prevents the zinc chloride from washing out. Chloride of zinc in conjunction with sodium fluoride is said to give good results.

Impregnation of sleepers with chloride of zinc was carried out at Kotri in Sind in 1864-65 and again at Phillour in the Punjab in 1868-69, but in each case the results were unsatisfactory.

(3) *Chloride of mercury* (corrosive sublimate) is a most effective substance for rendering wood proof against insects and decay. Its use as an antiseptic for timber was patented in 1832 by an Englishman named Kyan, and hence the process is known as kyanising. It is a useful method in dry situations, but useless in salt water. It has several disadvantages, the chief of which are its high cost and the violently poisonous nature of the substance used. Besides these disadvantages, corrosive sublimate affects iron.

the log to make the junction tighter and form a cavity between them. An oblique hole is then bored with an auger into the side of the log two or three inches from the thick end and leading into this cavity, and the nozzle of the pipe is inserted tightly into the auger-hole. The liquid is then turned on: at first only sap flows from the other end of the log, but gradually the impregnating liquid begins to come out, and when the outflowing liquid is sufficiently strong the process is complete. Usually several logs are placed in a row and injected simultaneously, each from a small branch pipe connected with the main pipe which leads from the raised tank. Sometimes a shallow metal plate, with sharp sides which can be driven into the end of the log, is used instead of a wooden board.

Another method of introducing the liquid is to saw the log almost through in the centre, which is then raised to open the cut. A ring of rope is placed in the cut, and the centre of the log is again lowered to its original position, when a chamber is formed in the middle of the log, into which the pipe is introduced through an auger-hole as before. By this method the liquid spreads outwards towards both ends of the log, and the impregnation is more rapidly accomplished than by the preceding method.

The hydrostatic method is suitable for injecting sulphate of copper and chloride of zinc. Its chief advantage is its simplicity and the cheapness of the apparatus required ; on the other hand, as the wood requires to be injected in the round a large proportion of the impregnated wood is wasted in conversion and much of the antiseptic substance is thus lost. Another drawback is the difficulty of transporting timber with the bark intact, and the impossibility of converting timber in the forest if this method of impregnation is to be adopted.

(2) PNEUMATIC INJECTION.

Pneumatic injection involves the use of pneumatic force to drive the antiseptic solution into, and in some cases the use of suction to withdraw sap and air from, the timber to be operated on. There are various methods of carrying out the pneumatic injection of timber, the main advantage of which is that impregnation is very complete : on the other hand the necessary plant is as a rule expensive, so that the cost of the work is comparatively high. There are various processes of

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pneumatic injection, of which the following deserve mention:—

(1) *Creosoting.*—For injection by this method the wood is first fully converted, and then tightly stacked on trucks wheeled into large horizontal iron cylinders, which are then tightly closed. The wood is first steamed for an hour at a temperature of $112\frac{1}{2}^{\circ}$ C., after which an air-pump is applied which sucks the air and moisture out of the wood by the creation of a vacuum. Creosote is then pumped in until the cylinder is full, and in order to force liquid into the wood a pressure of about 6 atmospheres is maintained for an hour, more or less, at the end of which time the liquid is withdrawn and the impregnated wood is removed from the cylinder. Sometimes the steaming process is dispensed with, the wood being dried instead.

The creosoting of sleepers and other converted timber is largely carried out in Europe. The plant required is expensive, but the method gives very satisfactory results, there being no waste of impregnated wood. To give the best results the wood should be thoroughly seasoned before creosoting.

(2) *Burnettising.*—As mentioned above, the salt employed for this process is chloride of zinc. The timber is subjected to a partial vacuum, and then immersed in a 1 to 2 per cent. solution of the salt. The advantages and disadvantages of chloride of zinc as an antiseptic have been mentioned on page 289.

(3) *Gardnerising.*—The wood is first steamed, dried, and again steamed with a chemical, the composition of which is a secret, in order to season it artificially. A strong solution of borax is then forced in pneumatically, and finally the wood is immersed either in chloride of mercury or creosote. During the process the timber is rendered non-inflammable by a method which is not revealed. The inventor claims that the value of the system lies in the chemical seasoning: it is more than probable, however, that the chloride of mercury or creosote, as the case may be, is the main factor in preserving the timber treated by this method. Little is known regarding the results attained by this process, which does not appear to have received any reliable trial in India.

(4) *Pfister's method.*—This is a method based on Boucherie's system of introducing antiseptic solutions into timber, but in this case the liquid is forced in by means of a

portable force-pump at a pressure up to 20 atmospheres. The pump can be transported to the forest, so that the wood may be injected before removal. By this process injection is more quickly carried out than by Boucherie's process, while it is immaterial whether the logs have bark on or not.

(5) *The Rüping process.*—This is a new process, the theory of which is that only sufficient antiseptic solution should be forced in to impregnate the cell-walls of the wood tissue, and not permeate the cell-cavities ; in this way considerably less solution is required than under other pneumatic methods, the cost being thereby reduced. In the Rüping process the wood is placed in a cylinder, and instead of a vacuum being first created in order to remove air and moisture, as in the usual creosoting process, the timber is subjected to a *pressure* of 5 atmospheres, air being thus forced into, instead of withdrawn from, the cellular spaces. The antiseptic solution is then forced into the cylinder at a slightly higher pressure, and when it is full the pressure is increased to about 15 atmospheres in order to force the solution into the timber. Any surplus liquid is forced out of the timber, when the external pressure is removed, by the internal pressure of the air in the cell-cavities, only the cell-walls remaining impregnated with the antiseptic.

Any of the usual antiseptic solutions can be used in this method, and it is claimed that the quantity of solution absorbed is less than $\frac{1}{2}$ to slightly over $\frac{1}{10}$ of that absorbed under the ordinary creosoting method, the cellular tissue of the wood being at the same time completely impregnated.

This process has not yet been in operation long enough to admit of a definite decision regarding its merits. If it turns out otherwise as satisfactory as the old creosoting method, it should possess a great advantage over it in the way of cheapness.

(3) THE OPEN TANK METHOD.

This method consists in immersing the wood in an open tank containing a hot antiseptic solution, in some cases leaving it in the solution till the latter cools down ; or the wood may be heated in a hot bath and then quickly transferred to a tank containing a cold solution of the antiseptic. The theory on which the process is based is that the heating of the wood produces a vacuum within it, the heated air inside it being expelled, and on subsequent cooling the vacuum sucks in the antiseptic solution, capillarity no doubt assisting in the process of absorption. The apparatus used consists of a tank either placed over a fire or fitted with coils of hot pipes for heating the solution.

The actual details of the process vary greatly, both as regards the temperature and strength of the antiseptic solution, and the length of time the wood has to be immersed. Hard close-grained woods require much longer immersion than softer and more porous woods, while wood which is to be subjected to a severe test as regards the conditions under which it is to be employed (for example in the case of railway sleepers, fence-posts, etc.) requires more thorough treatment than wood which is not to be so severely tested.

Generally the directions for use, which are supplied with the various antiseptic solutions on the market, are not reliable in the case of many of our Indian woods, which are comparatively hard and close-grained, since these directions are usually compiled after trial with the softer woods of Europe. Hence impregnation on an experimental scale should always be carried out with the woods which it is desired to treat on a large scale, before any extensive operations are undertaken, in order to determine the correct strength and temperature of the solution, and the period of immersion necessary to produce the desired result.

The great advantages of the open tank method, as compared with the pneumatic method, are that it does not ordinarily involve the use of expensive plant, and is therefore cheaper, while it can be employed in the neighbourhood of the forest, the apparatus being moved about from place to place as desired. Further, in the case of fence-posts, telegraph-poles, etc., it is possible to confine the impregnation to that portion of the pole which will be placed in or near the ground, thus still further reducing the cost of treatment. On the other hand impregnation by the open tank method is not so thorough as in the case of the pneumatic methods, and it remains to be seen whether or not the results will be equally satisfactory in India.

The open tank method is suitable for the various patent preservatives mentioned on pages 290 and 291. The employment of these is at present only in an experimental stage, but there should be a great future before any of the solutions which will stand the somewhat severe conditions to which timber is frequently subjected in India, and which are at the same time not too costly.

Among the earliest examples of the open tank method is the process known as *kyanising*, referred to on page 289 in which a weak solution (1 in 100 to 1 in 150) of chloride of mercury (corrosive sublimate) is used, the wood being immersed for 8 to 15 days in the liquid. A wooden tank is generally employed, since chloride of mercury corrodes iron. The highly poisonous nature of the chemical used, and its comparatively high cost, preclude the general adoption of the system in India.

Powell's process.—As mentioned on page 290, the preservative employed in this process is a saccharine solution with a small percentage of arsenic, and possibly other substances. The process is a form of open tank method, but differs from the usual open tank processes in requiring a somewhat elaborate plant, since it involves an artificial drying process whereby the wood is thoroughly seasoned as well as rendered more durable.

The timber to be treated is run into a tank through a door at its end on trucks running on a system of tram lines. When the tank is filled with timber the entrance door is closed, and the saccharine solution is run in cold until the wood is completely immersed. The solution is then gradually heated to boiling-point by a system of pipes, and kept at that temperature for a few hours, the time depending on the nature of the wood and the dimensions of the pieces. The solution, after being allowed to cool, is run off, and the wood is removed to drying chambers and subjected to a process of artificial drying.

Powell's process is reported to have given great satisfaction in Australia and elsewhere: it has been tried to some extent in India, so far with favourable results, though further trials extending over a period of years will be necessary before any definite decision as to its merits under Indian conditions will be possible. Powellising is a more expensive process than the ordinary open tank methods, but it has the great advantage that green wood may be used, and becomes thoroughly seasoned during the drying process.

(4) THE BRUSH METHOD.

This consists in applying the antiseptic solution to the surface of the wood with a wire brush, the solution being generally heated and two or three coats of solution being applied. Various antiseptics may be employed under this method, such as *Avenarius carbolineum* (heated to 65°—94°C.), *Jodelite* (heated to 82°—94°C.), *Solignum* (cold or heated to 160°—180°F.), *Microsol*, *Crésoyle*, and other substances. The impregnation by this method is not so complete as in the open tank method.

SECTION III.—HASKIN'S PROCESS.

It is well known that if wood be charred in a fire the portions rendered more durable by the process are not only the layers in actual contact with the fire, but also those immediately inside the blackened exterior, that is, as far as the heat of the fire has much effect. The reason why these tissues become more durable is that the albuminous and other substances of the sap become chemically changed by the heat, and converted into antiseptic substances which resist the attacks of insects and fungi. Acting on the knowledge which this fact affords, Colonel Haskin, an American, has devised a method of heating wood to such a temperature that its sap is converted into antiseptic substances: this process is known as the haskinising or vulcanising of wood. The actual process of haskinising is simple, consisting as it does of placing the wood in a strong closed iron cylinder, into which is driven dry superheated air at a temperature between 200° and 400°F. and under a pressure of about 13½ atmospheres (200 lbs. per square inch). The air requires to be kept circulating in order to maintain it in a dry condition; hence the moist air generated within the cylinder is carried off, fresh dry air being pumped in. The pressure is necessary to prevent the disintegration of the wood which would take place otherwise: for the same reason care has to be taken not to maintain too high a temperature. The time during which the wood is kept in the heating cylinders depends on its dimensions; for sleepers it is about 8 hours.

Timber treated by the haskinising process is claimed to be more durable as well as stronger than wood not so treated. The cost is small if regular supplies of wood are available for treatment, while it has the great advantage over other processes that the hardest woods can be successfully dealt with. On the other hand, the process is suitable only for green timber, but as the timber may be converted this is not a serious drawback. Such trials as have been made in India with wood treated by this system have not given very satisfactory results, but as the trials have not been sufficiently exhaustive, it would be premature to condemn the system on present evidence.

CHAPTER IX.

The Pressing and Baling of Hay.

SECTION I.—GENERAL.

The pressing and baling of hay is of great importance for purposes of storage and transport, and during famine operations; where hay has to be transported rapidly to considerable distances from the places of collection, pressing operations on a large scale form an important part of a Forest Officer's work. Ordinarily hay, if properly stacked, improves by keeping, at any rate for one or two years. So far as is known, unpressed hay commences to deteriorate in the third year, whereas, according to Dr. Voelcker, hay if properly pressed keeps good for many years: the importance of this fact is very great, should Government ever decide to maintain stocks of hay for use in years of scarcity. It may be added that pressing decreases the inflammability of hay. It is obviously useless, however, to go to the expense of pressing and baling hay if it is within easy reach of the place of consumption, if it is to be used within a year or two of cutting, and if there is ample storage space. On the other hand the cost of stacking bales of hay is estimated to be only $\frac{1}{2}$ to $\frac{1}{4}$ of the cost of stacking the same weight of loose hay, so that the cost of pressing is to some extent compensated for.

Hay-making has been described briefly on page 159. If possible only the better kinds of fodder grass should be utilized, and this point should be borne in mind in selecting grass-cutting areas. So far as our present knowledge goes, different grasses appear to have different keeping powers, and hence each bale should contain as far as possible only one species of grass. It is essential that the grass should be properly dried, otherwise it will ferment in the bales, but it should not be exposed to the sun unnecessarily long. The requisite degree of dryness can be tested by burning small wisps of grass, when a residue of anything but ash indicates that further drying is necessary. Baling should be done as soon as possible after the hay is made, and certainly within six months, as the hay becomes brittle if kept long.

The size and weight of the bales must depend on requirements. The various methods of pressing are noted below, but it may be mentioned here that they can be pressed into considerably smaller bulk by machinery than in hand presses. It is of great importance that the bales should fit exactly into the vehicle in which they are to be transported, without loss of space: this applies not only to railway trucks but also to carts. The weight of the bale is also an important consideration: in forest operations it is generally found that bales of over 180 lbs. are somewhat heavy to handle. For mule transport 80-lb. mechanically pressed bales are most suitable. The weight of a bale varies much according to the species of grass: towards the end of the season also, when the grass dries up, it loses weight.

The bales are usually bound with four or five ties, made of wire, cane or rope. On the whole wire makes the most satisfactory though perhaps not the cheapest ties. The tighter the bales the stronger are the ties required: in tight bales, however, the ties are less liable to come undone than in loose bales. The fastenings of the ties should be as simple as possible. To save expense arrangements should be made for ties to be returned when done with, or they should be disposed of to purchasers of hay at a reasonable price.

There are many different kinds of presses on the market, which can be classified under one or other of three main types, according as they are operated by (1) *mechanical power*, (2) *animal power*, and (3) *hand power*. As might be supposed, the question of the best type of press to employ must depend very largely on the conditions of each particular case, and some remarks on the suitability of the various types of presses under different conditions are therefore necessary.

SECTION II.—PRESSES OPERATED BY MECHANICAL POWER.

Under this head are included presses operated by steam, hydraulic presses, and those worked by water-power or electricity. So far as is known, water-power has not yet been employed for pressing hay in India, while for hay-pressing in or near the forest electric power is at present out of the question. Mechanical presses, of whatever type, vary largely in price according to power, but a complete plant, with engine, will always cost several thousands of rupees. Where operations are on a large scale economies can be effected by working several presses with one engine. These presses are not as a rule suitable for use in out-of-the-way places, as their manipulation requires skilled labour, repairs would be difficult to effect, and the cost of transport and erection would be heavy: they are also unsuitable for localities where fuel and water are not easily obtainable. Mechanical presses, however, are eminently suited for use on a railway if there is a large demand from a distance for hay, and if the grass areas are within easy reach, so that the cost of transport of grass to the press is not prohibitive.

Since mechanical presses can press a given quantity of hay into much smaller bulk than hand-presses, they have immense advantages in the case of transport to a distance: other advantages are decreased inflammability, reduction in the space required for storage, greater security against the loosening of the bales, and, it is believed, better preservation of the hay. Again, larger quantities of hay can be dealt with by mechanical presses, than by hand-presses, and much less manual labour is required for a given outturn: this is an important consideration if large quantities are required in a short space of time, and all available labour is required for cutting and carting.

Steam-pressed bales are estimated to cost roughly 1 anna per maund more than hand-pressed bales, but even allowing for this, in the case of long railway journeys the saving in freight alone is very considerable, since railway companies, as a rule, charge, within certain limits, by the truck-load and not by weight. Thus it is estimated that an ordinary broad-gauge truck will take at most 70 maunds of hand-pressed hay as against a minimum of 225 maunds of steam-pressed hay, that is, the freight on hand-pressed bales is at least three times that on steam-pressed bales. In large grass operations this is an important consideration, for, to take an example, with freight at 2 annas per truck per mile the saving in freight alone for conveying 10,000 tons a distance of 200 miles would be R62,222; after deducting R17,500, the difference in cost of pressing at 1 anna per maund, the net saving would be R44,722. With longer journeys and higher freights the saving would be considerably greater.

Hydraulic and steam presses will turn out bales weighing from 25 to 30 lbs. or over per cubic foot, whereas bales pro-

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duced by hand-presses rarely weigh more than 8 lbs. per cubic foot. Trials carried out with Jessop's hydraulic press showed that two presses worked by one engine could turn out 973 bales weighing 79 to 80 lbs. each, that is, 25 lbs. per cubic foot, in 20 hours. In the grass operations of Indore State during 1911-12, Howard's Patent Perpetual Lion Press is reported to have proved most satisfactory. This press is capable of turning out bales of various sizes, from 40 lbs. upwards. One 10″ cylinder portable 8-H. P. engine by Marshall and Sons, costing ₹3,500, was employed to work three of the presses. The cost of each press, including freight and other charges, came to ₹2,700.

A steam press which is now on the market, and which from its description would seem to be a suitable form of press for forest work in India, is Chandler's patent steam press.* This press, which is composed entirely of iron and steel, has been specially designed for use in India, and is free from most of the complicated gear which is a feature of many types of steam press. The pressure is exerted horizontally by means of a patent worm gear, and a density of 25 lbs. per cubic foot is obtained with hay of suitable quality. Besides simplicity of construction this press has two great advantages, first that it is mounted on a travelling carriage and can therefore be transported readily from place to place, and second that it is specially designed for pressing the 80 lb. bales required by the Military authorities, though it can also produce bales of all sizes up to 200 lbs. in weight. One 12 H. P. engine can work two to four Chandler's presses, and it is claimed that each press can turn out 200 maunds a day, at a maximum cost, inclusive of everything, of 2 annas per 80 lb. bale.

SECTION III.—PRESSES OPERATED BY ANIMAL POWER.

Presses operated by animal power have apparently not been much used in India so far, but are now under trial in the Madras Presidency. These presses are much less cumbersome than steam presses; and are comparatively inexpensive, costing ₹1,500 or less. They produce bales weighing 15 to 20 lbs. per cubic foot. Particulars of outturn and cost are not available. Old cotton presses, converted for pressing

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* Obtainable from Messrs. Macbeth Bros. & Co., Bombay.

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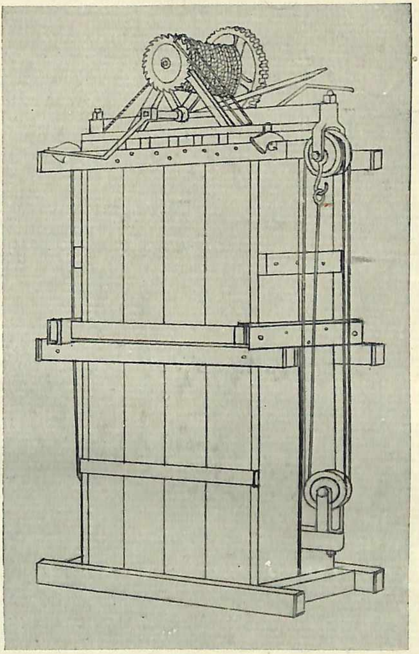
hay by animal power, have been used in the Bombay Presidency, but these have not been found very satisfactory, as they work slowly, giving a smaller outturn than hand-presses, while the bales are too bulky and heavy to handle with convenience. There would appear to be scope for development in the designing and working of animal power presses suitable for Indian conditions.

SECTION IV.—HAND PRESSES.

For forest operations in India hand presses have hitherto played a far more important part than steam presses or animal power presses, for in spite of the many advantages of steam presses, under certain conditions hand presses possess some great advantages. Generally speaking, it may be said that where the distance to which the bales have to be transported is not great, where labour is plentiful and cheap, and where the hay has to be stored for not more than 3 years, hand pressing is more economical than steam pressing. Hand presses are especially suited for use in distant and scattered forests, where the erection and working of steam presses would be impracticable ; their use is also indicated in places where there are no centres on or near a railway or other main line of communication to which quantities of hay can be brought for pressing on a large scale. Thus hand presses must always play an important part in pressing operations in the forest.

Hand presses are of various different types, some vertical and some horizontal; they may be worked by means of levers, chains, cog-wheels, screws, winches or pulleys, or combinations of these, while there are also hand presses on the hydraulic principle. Hand presses are considerably cheaper than other forms of presses, costing ordinarily from R400 to R500 each. It is essential that they should be simple in design, portable, and strong : the constant breakdown of presses, so common a feature of famine operations, requires to be guarded against by the selection of a suitable type of press.

The outturn of hand presses varies greatly. Some of the older types of presses produce on an average from 3 to 6 bales of 150 lbs. each per hour at a cost (including labour for pressing and wire ties only) of about 1½ to 2 annas a bale. This outturn, however, is considerably exceeded by improved forms of presses, such as the Irani press described below, TYPES OF HAND PRESSES FOR BALING HAY. PLATE XXVI.



1. THE IRANI PRESS.

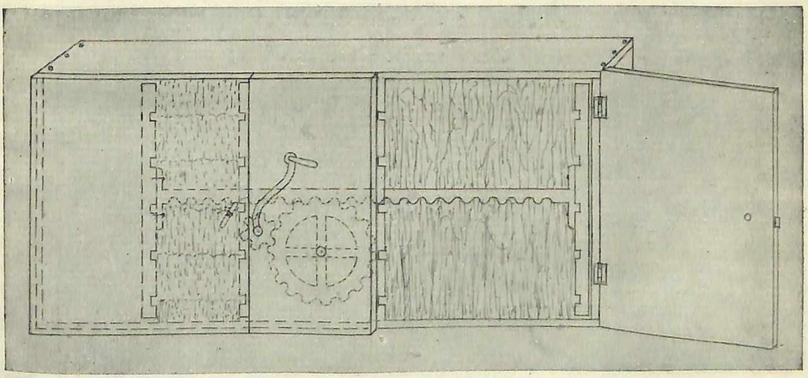


Photo.-Mechl. Dept., Thomason College, Roorkee.

2. A SIMPLE HORIZONTAL BOX PRESS.

[To face page 302.

which turns out 8 to 10 bales of 180 lbs. each per hour. The density of pressing is ordinarily 5 to 8 lbs. or in rare cases 9 or 10 lbs. per cubic foot. Generally speaking hand pressing reduces the bulk of hay to about $\frac{1}{3}$ the bulk of loose hay. In the famine operations of 1907 in Kheri Division, United Provinces, a daily average outturn of 15 bales of 160 lbs. each per press was obtained with box type presses, worked with levers and pulleys, purchased from Messrs. Geo. Gahagan & Co., Bombay, at a cost of R450.

A detailed description of all the different forms of hand presses on the market is beyond the scope of this book, and a few examples of special types of presses will be sufficient.

Vertical hand presses.—The main principle in most vertical hand presses is the same, namely, that of a horizontal "platen" or bottom table which moves upwards inside a closed box and presses the hay against the top of the box. Differences of detail lie mainly in the gear which operates the movable platen.

Of the various type of hand presses which have found practical trial in India the one which has proved most satisfactory is the Irani press* (see Plate XXVI, fig. 1).

This press is made up of two parts, (1) the body, which is made of wood and is meant to receive the hay for pressing and (2) the machinery, which is all iron, fitted on the top of the body. The press is made in two sizes, of which the larger is generally used, having been proved to be more economical in every way. The bales turned out of the larger sized presses measure 4 feet in length by 2 feet broad and $2\frac{1}{2}$ feet to 3 feet high, and weigh on the average 180 lbs. each, the density being $7\frac{1}{2}$ to 9 lbs. per cubic foot. The bales of the smaller size weigh 100 lbs. each, the dimensions being proportionately smaller. The larger press costs R500 and weighs about 20 cwts. and the smaller press costs R400 and weighs about 16 cwts.

The body of the press has two openers at the sides, opening outwards on wooden hinges, for packing hay in; these are closed and held in position by iron catches at the top corners before the machinery is put in motion. The top is rigidly secured to the body. A bottom table or platen is provided inside the body by the lifting of which, with the aid of the machine gear at the top, the grass in the body is pressed between it and the top. The body is sunk in the ground to the

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*This press, obtainable from Messrs. Richardson and Cruddas, Bombay, is the invention of Mr. J. H. Irani, of the Bombay Forest Department.

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level of the hinges, or an elevated platform is erected at the same level, to facilitate the loading of the hay into the press.

The machine gear consists of a specially designed winch with handles operating geared spur wheels by which the power is multiplied and transmitted to the barrel of the winch. The barrel has right and left hand spiral grooves formed on its circumference. To this barrel are attached flexible steel wire ropes which ride on the spiral grooves mentioned, and which gradually converge towards the centre. The wire ropes on leaving the barrel are carried over the sheaves of a pair of double or treble sheaved pulley blocks secured rigidly to the ends of the top and of the vertically moving bottom table. Thus the hand power when applied to the winch operates the wire ropes and draws up the bottom table *truly horizontal* until the hay is sufficiently compressed. When this has been done the pawl engages with the ratchet wheel and prevents the slacking back of the wire ropes when the power is no longer operating. The wire ties are then fixed on the pressed bale (for which grooves are provided in the bottom table and the top), the pawl is released from gearing with the ratchet wheel, and the ropes are then allowed to slack back by means of a band brake worked through a lever which controls the descent of the bottom table and releases the pressed bale, which is then removed, and the operation recommences.

The press is worked by two men, with the aid of 2 more men who help in feeding the body with grass, in binding wire ties, etc. The outturn is 8 to 10 bales per hour.

One of the commonest of the old type of presses consists of the body with openers and the bottom table as in the Irani press, but has no winch arrangement, the bottom table being lifted up by means of two separate sets of gear worked with levers, each set being fitted on the opposite sides of the press. The set of gear consists of a double ratchet wheel with a grooved recess between to receive the links of a steel chain, the ratchet wheel being operated by a wooden lever worked up and down. A catch is provided to keep the ratchet wheel in position so as to prevent the chain slacking back. The chain from the ratchet wheel is carried round a pair of sheaves secured rigidly to the bottom table, which is lifted upwards as the lever operates and the chain is pulled up through the grooves of the ratchet wheel. There are many defects in this type of press, which have been eliminated in the

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Irani press. The bottom table, being worked by separate systems of gear at each end, seldom moves horizontally, and frequently jams, causing delay or breakage. The gear itself is unsatisfactory, there being much wear and tear on the teeth of the ratchet wheels, which are liable to break. The size and weight of bales turned out by these presses is the same as in the Irani press, but hardly six bales are turned out per hour even when the presses work smoothly. Other types of presses dispense with the chains and wheels, the bottom table being raised by levers working in vertical racks.

Horizontal hand presses.—A simple type of horizontal press is that shown in Plate XXVI, fig. 2. The press consists of two compartments with doors opening at one side. In the diagram the door of the left-hand compartment is shown closed and that of the right-hand compartment open. The pressing force is applied by means of a couple of handles which turn cog-wheels engaging on a toothed bar having a movable platen at each end. The bar is moved alternately backwards and forwards so that while pressure is exerted in one compartment it is released in the other. Each compartment is thus filled with hay in turn, and a bale is pressed in each alternately. In the diagram the left-hand compartment contains pressed hay and the right-hand compartment loose hay.

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